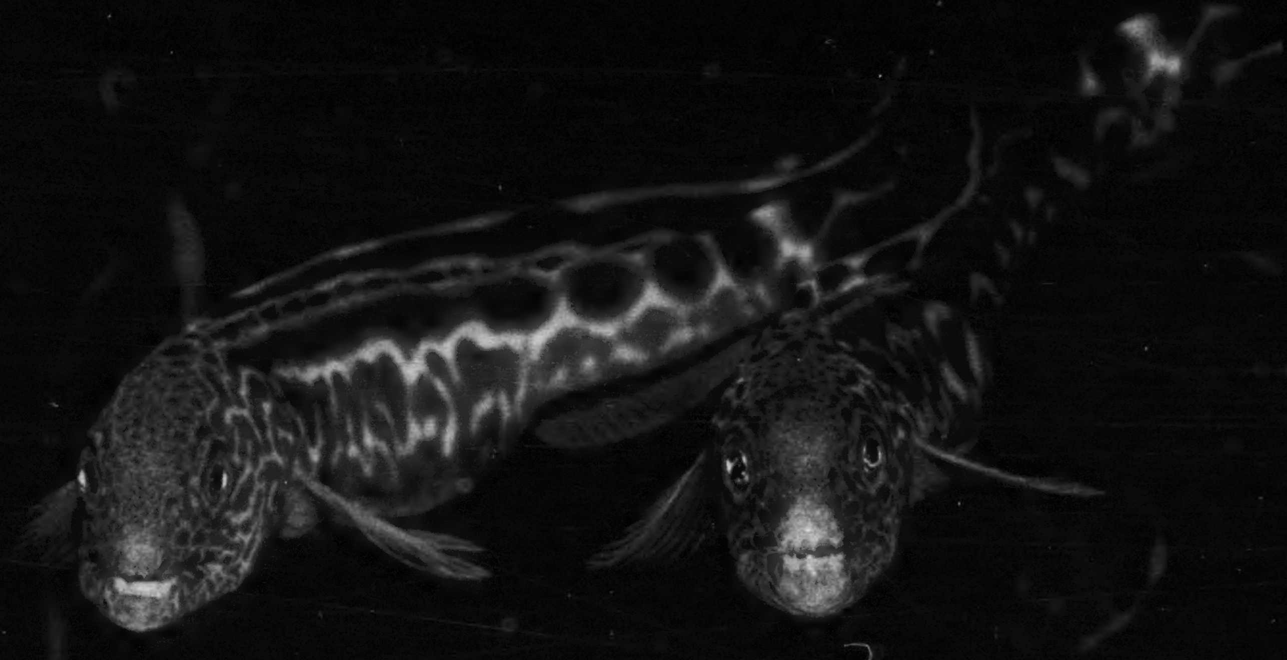
Canadian Aquaculture
R&D Review
2011



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- Finfish: Freshwater, Salmon and Marine
- Shellfish
- Sea Lice
- Environment Interactions

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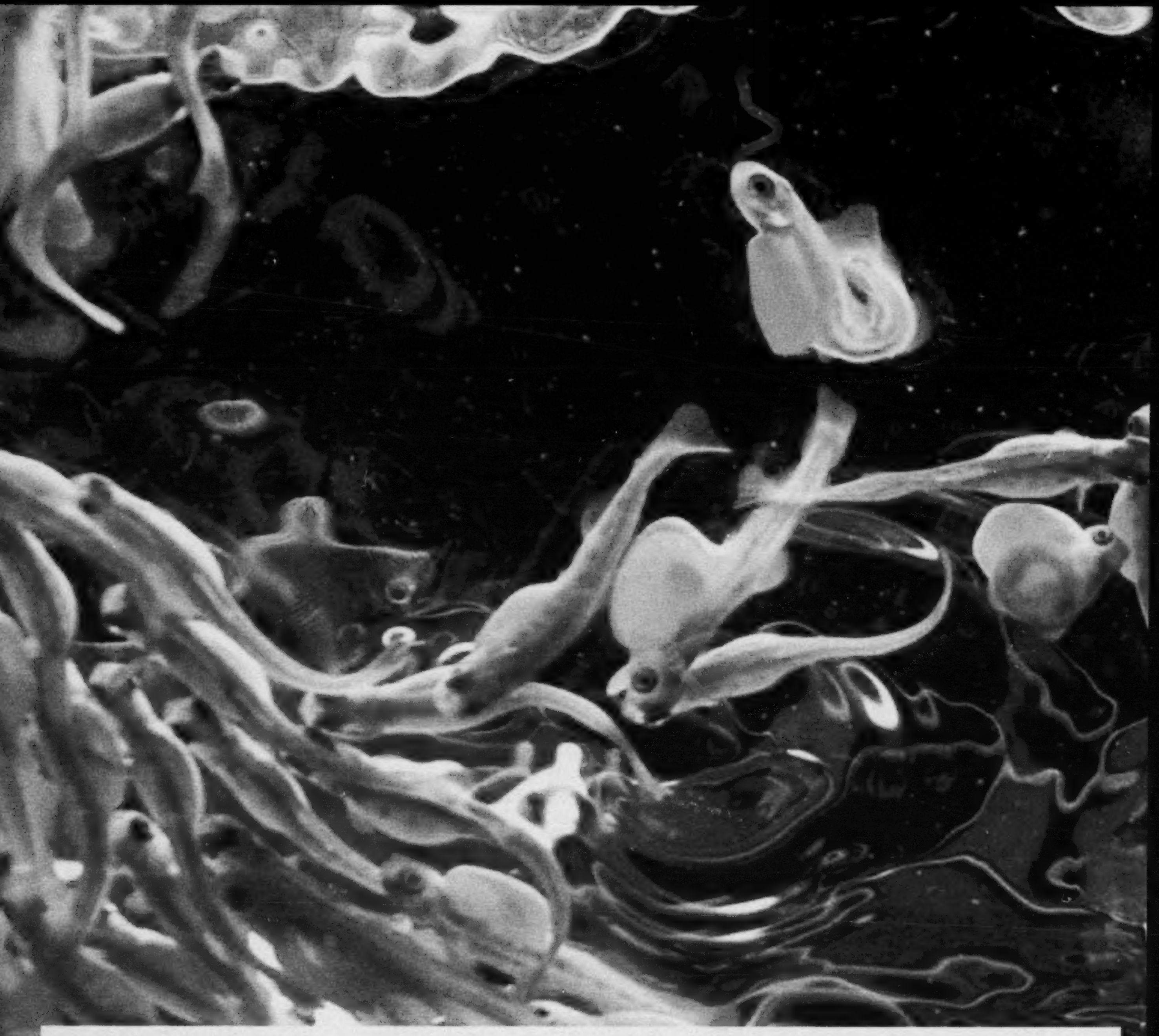
Special Publication 16

Canadian Aquaculture R&D Review 2011 • Special Publication 16



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Editors
D. John Martell, Ingrid Burgetz, Johannie Duhaime and G. Jay Parsons

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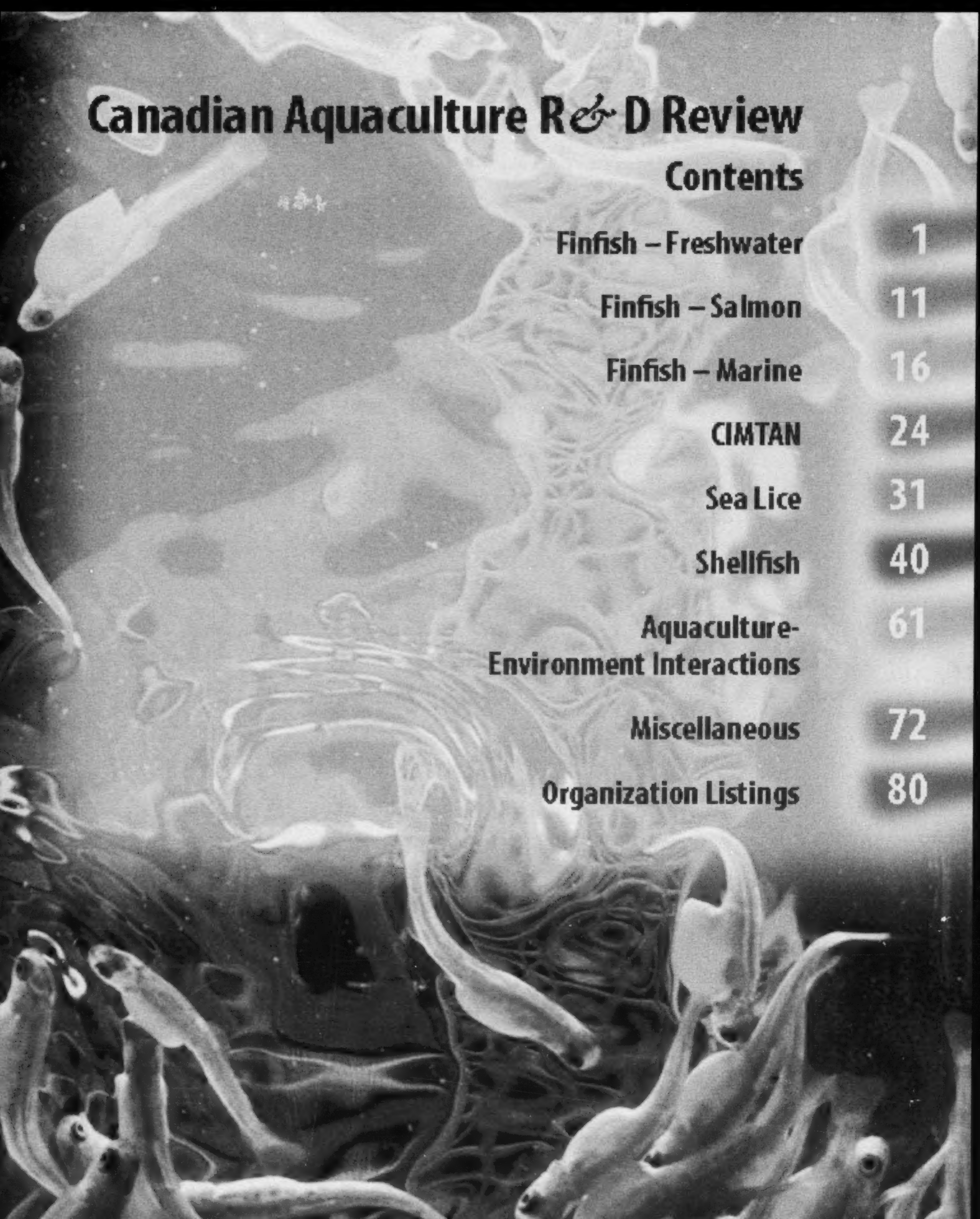

Canadian Aquaculture R& D Review

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Introduction

Welcome to the fourth edition of the biannual Canadian Aquaculture R&D Review. The review is an ongoing compendium of the aquaculture R&D projects that have been underway over the past two years from all across Canada. The review contains over 220 project descriptions detailing an impressive range of topics, disciplines, and species from across the vast geography of Canada. Projects include marine and freshwater species, with topics ranging from fish health, production, husbandry technology to nutrition, genomics, environmental interactions, and more.

This issue represents a turning point in our ongoing efforts to mobilise aquaculture knowledge in Canada. Since the outset of this initiative, the support of Dr. Al Castledine, the partnership with BC Innovation Council (BCIC through the BC Aquaculture R&D Committee - BCARDC) and contributions of Peter Chettleburgh, Dr. Tim DeJager and others were critical in positioning the R&D Review as an important vehicle in articulating our collective national research efforts in facilitating a sustainable aquaculture sector in Canada. With the retirement of Al and refocus of the BCIC, we have now evolved to the development of a partnership with the Aquaculture Association of Canada (AAC) in the production of this issue of the review. This new partnership is ideal, highly relevant and mutually beneficial to our roles in the area of knowledge mobilisation for both the AAC and Fisheries and Oceans Canada (DFO) and has allowed us to produce this 2011 edition in a new format as an AAC Special Publication.

The AAC is the only national organisation that focuses on the education, scientific and technological development and advancement of aquaculture in Canada. The two principal ways by which the AAC does this is through the annual Aquaculture Canada conference and through publications like this one and the regular AAC Bulletin series. Publishing the Canadian Aquaculture R&D Review helps fulfill this mandate to members, while also providing an easy and attractive way to reach a larger audience.

Since the AAC was incorporated in 1984, there has been an approximate 25-fold increase in Canadian aquaculture production value. Throughout this time, including to the present day, Canada has been a world leader in aquaculture innovation, driven by an active research community committed to the sustainable development of this industry. This current R&D Review documents our strengths as a nation in support of sustainably farming aquatic resources for our own populations and for export. As well, during this period of time there have been many changes in the types and approaches to funding R&D in Canada. During the last two years there have been further changes in the research landscape, with the most notable change being the funding of the NSERC Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN). This new network, described herein, highlights a multi-disciplinary and multi-partnered approach in developing an innovative alternative approach to the sustainable development of the aquaculture sector, namely integrated multi-trophic aquaculture (IMTA).

We would like to take the opportunity to recognise and thank several people who contributed significantly to the production of this review. Dr. John Martell undertook the overall coordination of this project and was instrumental in seeing this project through completion. Ingrid Burgetz provided key support in reviewing and editing all submissions, as did Johannie Duhaime, who assisted with the review and collation of projects and the content-editing of the French version of this Review, Pat Hunter who contributed her design expertise and many photos to this project, and Nancy House who provided critical copy-editing of the final pre-press version. We would also like to thank Susan Waddy, the AAC Home Office Manger, for overseeing AAC's part in this publication, as well as Lindsey Henderson (Intown Creative) for her work on the design and layout of this issue.

Jay Parsons, PhD
Oceans and Science Sector
Fisheries and Oceans Canada

Tillmann Benfey, PhD
President
Aquaculture Association of Canada

Upper temperature tolerance in Arctic Charr

Understanding how fish deal with warm water and how to limit or prevent summertime mortality is a critical issue for our company. The natural range of Arctic Charr is the most northerly of all the salmonid species and intensive culture is typically limited to regions where water temperatures are not expected to exceed 15°C on a regular basis. Our approach to improving upper temperature tolerance in Arctic Charr involves both molecular genetics, performed in collaboration with Dr. William Davidson at Simon Fraser University (SFU), and traditional breeding techniques employed by Icy Waters.

At SFU, samples of heat sensitive and heat tolerant fish have been analyzed using a 32K microarray developed for salmonids by cGRASP. Eighty-four genes that are only expressed in fish with high upper temperature tolerance have been identified. At Icy Waters, we have recently established a select line of warm water tolerant broodstock and are attempting to estimate the heritability of this trait in our strains. We have also produced several backcrossed families that will be used in linkage studies to identify genetic markers associated with temperature sensitivity. By understanding the mechanism by which Arctic Charr endure warm water temperatures, we hope to breed a strain that is more resistant to temperature stress.

Sept. 2006 – ongoing • Funded by: Icy Waters Arctic Charr Ltd., Natural Sciences and Engineering Research Council of Canada (NSERC)
Project team: Colin McGowan, William S. Davidson
Contact: Colin McGowan (cmcgowan@icywaters.com), William S. Davidson (wsdavids@sfu.ca) • www.icywaters.com

Jonathan Lucas (Icy Waters Arctic Charr Ltd.)

Icy Waters' facility in the Yukon

Sean Irvine (DFO)

Small sturgeon at Target Marine facility

Innovative technology for Canada's White Sturgeon aquaculture industry

Sturgeon products, including caviar, represent highly sought-after commodities across the globe. The successful development of Canada's White Sturgeon aquaculture will enable the production of White Sturgeon caviar, which will boast one of the highest values of all Canadian agriculture products. Operating under the highest environmental performance and traceability, Canada has the potential to become a new competitor in the global farmed caviar trade, while helping to alleviate pressure on endangered wild stocks.

This project designed modifications to a Recirculating Aquaculture System (RAS) to retrofit two existing outdoor reuse tanks, in order to provide fine control of the sturgeon rearing environment while conserving water and energy.

The new system reduces water use between 98 and 99%, and has resulted in considerable energy savings. Additionally, it allows Target Marine to heat tanks to a temperature appropriate for sturgeon culture, and the increased temperature has resulted in higher feeding rates. The system efficiently removes solids, carbon dioxide, and ammonia from the water.

Target Marine anticipates that the use of this technology could reduce the time to maturation and caviar production. These technical improvements are driving scientific excellence and best practices for sustainable resource use.

Aug. 2009 – Apr. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Target Marine Hatcheries Ltd., Community Futures – Sunshine Coast, Vancouver Island University, Freshwater Fisheries Society of BC, University of California Davis
Project team: Justin Henry (General Manager, Target Marine Hatcheries Ltd.), Robert Haines, Lorraine Fowles, John Percy (Target Marine Hatcheries Ltd.)
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Optimizing fish oil supplementation in the feed of commercially grown Arctic Charr

Arctic Charr have the most northerly distribution of any freshwater finfish and have evolved to exploit an environmental niche where other salmonids, such as Atlantic Salmon, do not thrive. Consequently, a commercial diet formulated for Atlantic Salmon might contain more fat than that required by Arctic Charr for healthy growth. The objective of this project was to investigate the dietary fat requirements of Arctic Charr and determine whether the amount of supplemented fish oil in their feed can be reduced. Fish were offered either a high fat (26%) or low fat (18%) diet under commercial conditions. After 12 months, no significant difference in growth rate, food conversion ratio (FCR), rate of maturation and mortality was observed between the two groups. The average fat content of fillets was similar in both groups, but more consistent in fish fed a low fat diet. Flesh quality and organoleptic analysis demonstrated a preference for fish fed the low fat diet. Decreasing the level of fat supplementation will lower the cost of production and improve the sustainability of Arctic Charr aquaculture by reducing its dependence on fish oils derived from the wild fishery. It might also improve the quality and taste of the final product.

Apr. 2007 – ongoing • Funded by: Icy Waters Arctic Charr Ltd.
Project team: Jonathan Lucas (Icy Waters Arctic Charr Ltd.), Colin McGowan (Icy Waters Arctic Charr Ltd.), John Rose (Icy Waters Arctic Charr Ltd.), Brad Hicks (Taplow Feeds International)
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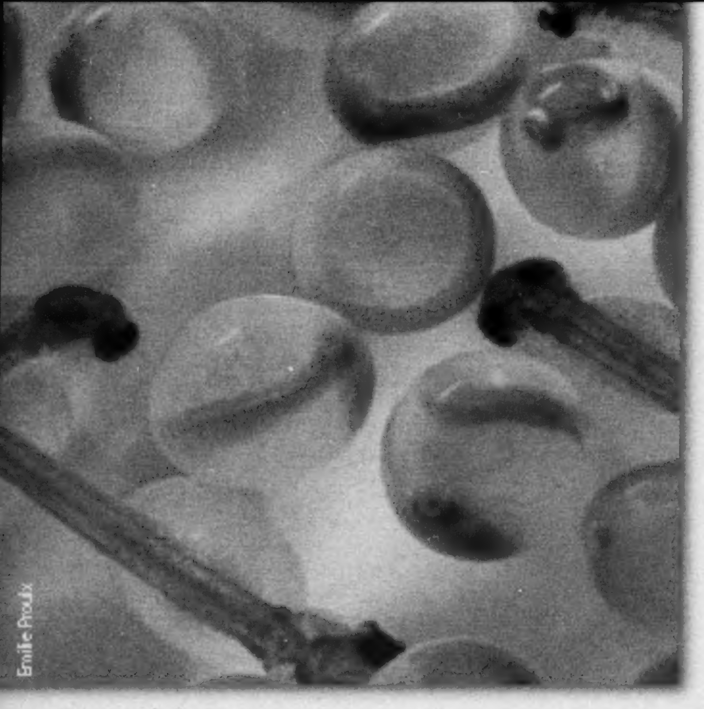

Eggs and alevins

Selection and breeding program for Rainbow Trout in Canada

One priority of the freshwater aquaculture industry is the establishment of a national broodstock program to develop enhanced performance in Rainbow Trout, specifically targeting improved fillet yield, enhanced growth rate and greater tolerance to warm-water conditions.

As first steps in this process, IPSFAD and partners held two workshops on the development of a *Selection and Breeding Program for Rainbow Trout Aquaculture* in Canada. With the results from the first workshop as a base, the *Selection and Breeding Program for Rainbow Trout Aquaculture in Canada* was poised to begin Phase II – development of a framework and a directed workshop to discuss implementation of the framework. At the end of the second workshop, five conclusions were drawn as to what the next steps should be toward structure and implementation of a *Selection and Breeding Program for Rainbow Trout in Canada*.

Progress is made with regards to these conclusions. There is interest in all involved parties (industry, government, not-for-profit, and researchers) in initiating a selective breeding program. A committee has been formed including primarily industry stakeholders (producers and growers). Action items are been executed and the *Selection and Breeding Program for Rainbow Trout in Canada* is continuing its progress towards a finite structure and an implementation date.

Jan. 2009 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Natural Sciences and Engineering Research Council of Canada – Strategic Workshops Program, DFO – National Aquaculture Strategic Action Plan Initiative, Northern Ontario Aquaculture Association, National Research Council - Industrial Research Assistance Program (NRC – IRAP)
Project team: Andy Robinson, Amber Garber, Rich Moccia, Grant Vandenberg, Eric Boucher, Karen Tracey, David Bevan
Contact: Andy Robinson (andyr@uoguelph.ca) • www.ipsfad.ca

Mechanism(s) of toxicity and sub-clinical effects of DON in Rainbow Trout

Contamination of feeds with mycotoxins is becoming an issue of increasing importance in aquaculture due to the use of high levels of plant ingredients. In a previous study conducted in the UG/OMNR Fish Nutrition Research Laboratory at the University of Guelph, we found that Rainbow Trout were extremely sensitive to low dietary levels of the *Fusarium* mycotoxin, deoxynivalenol (DON). Consequently, this study will seek to determine the basis of this sensitivity by examining the mechanism(s) of toxicity and sub-clinical effects of DON, in Rainbow Trout. Specifically, the effects of diets containing low, graded levels of DON from naturally contaminated corn, on pathological changes of various tissues and organs will be examined. Additionally, the effects of DON on protein synthesis and degradation pathways will be examined using *in vitro* cell culture studies. Finally, this project will seek to identify potential nutritional strategies to mitigate the adverse effects of DON on the health and performance of Rainbow Trout.

Sept. 2010 – Sept. 2013 • Funded by: Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Ontario Ministry of Natural Resources (OMNR)
Project team: Jamie M. Hooft (U of Guelph), Dominique P. Bureau (U of Guelph), Iban Seiliez, John Lumsden, Neil Karrow • Contact: Jamie M. Hooft (jhooft@uoguelph.ca), Dominique P. Bureau (dbureau@uoguelph.ca)

Canadian model farm initiative

Development of a land-based "model farm" program is a priority initiative within the 3rd Industrial Action Plan of the Interprovincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD). The *Manitoba-Canadian Model Aqua-Farm* is a production unit that effectively integrates current technologies in terms of nutrition and feeding strategy, fish health management, design of infrastructure and equipment, water conservation and utility, manure processing and management, production management and operational practices and standards in an effort to optimize both financial and environmental performance.

The first model farm was built in a vacant barn at Riddell's Roasters, a broiler operation located near Winnipeg, MB. Construction was completed in the autumn of 2010 and, after stocking a test batch of fish, the first two cohorts of Rainbow Trout were delivered in November (40,000 at 20 g and 40,000 at 5 g).

From 2011 through 2013, a comprehensive monitoring program will be implemented to collect, compile and analyze performance and environmental information and data from the facility, providing a detailed understanding of all operational aspects of the model farm. The initiative is intended to generate knowledge and validate technologies and practices to help overcome some of the principal challenges associated with the commercialization of intensive, land-based recirculating aquaculture. By establishing fundamental operational, environmental and economic benchmarking information, the *Manitoba-Canadian Model Aqua-Farm* will contribute to the sustainable development of freshwater aquaculture throughout Canada.

2008 – 2013 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Riddell's Roasters Inc, Manitoba Agriculture, Food and Rural Initiatives, DFO – Aquaculture Collaborative Research and Development Program (ACRDP), National Research Council - Industrial Research Assistance Program (NRC – IRAP)
Project team: Grant Vandenberg, Dan Stechey, Jeff Eastman, Bill Robertson, Eric Boucher, Rudy and Leslie Reimer
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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Oncorhynchus mykiss

Rainbow Trout sensitivity to feed-borne *Fusarium* mycotoxin deoxynivalenol (DON)

The effects of feeding diets containing low, graded levels of deoxynivalenol, a *Fusarium* mycotoxin from naturally contaminated corn, on the performance, health and apparent nutrient digestibility of Rainbow Trout were investigated. Diets with increasing levels of DON (0.3, 0.8, 1.4, 2.0 and 2.6 ppm) fed over eight weeks to Rainbow Trout (initial weight = 24 g/fish) resulted in significant decreases in feed intake, growth and feed efficiency of the fish. A pair-feeding control treatment indicated that the fish fed the diets contaminated with DON had lower efficiency of nutrient utilization than the control diet. Contamination of the feed with DON had no effect on apparent digestibility of crude protein and gross energy. Some morphological changes of the liver were noted in fish exposed to DON. These results suggest that Rainbow Trout are extremely sensitive to DON from naturally contaminated grains and that the effects of DON on Rainbow Trout are not simply related to a reduction of feed intake, but rather, are due to deleterious metabolic effects.

Sept. 2007 – May 2010 • Funded by: Biomin (Austria), Ontario Ministry of Natural Resources
Project team: Jamie M. Hooft (U of Guelph), Dominique P. Bureau (U of Guelph), Abd El Hakeem, Ibraheem Elmor, Pedro Encarnação
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Nutritive value of novel products fed to Rainbow Trout and Atlantic Salmon

Indian Mustard (*Brassica juncea*) is a drought resistant rapeseed variety produced in Western Canada. Recent cultivars low in glucosinolate and erucic acid have been developed and are now widely cultivated. This research project focused on the evaluation of the nutritive value of two novel Indian Mustard products, a protein concentrate containing about 62% protein and a meal containing about 44% protein. The digestibility and bioavailability of amino acids in these products were evaluated in two salmonid species, Rainbow Trout (*Oncorhynchus mykiss*) and Atlantic Salmon (*Salmo salar*) and compared to those of a commercial soy protein concentrate (55% protein) commonly used in salmonid feeds.

Apparent digestibility of crude protein and essential amino acids in these novel ingredients was as high and similar to those of the soy protein concentrate. Results also suggested that the high concentration of phytic acid of the Indian Mustard protein concentrate could potentially affect digestibility of some amino acids at high incorporation levels. A growth assay confirmed that bioavailability of amino acids in Indian Mustard protein concentrate and meal was high. This study indicates that Canadian-grown Indian Mustard products have a high nutritive value and very good potential for inclusion in salmonid diets.

Sept. 2006 – Aug. 2010 • Funded by: Bio-Extraction Inc., OMNR
Project team: M.A.K. Chowdhury (U of Guelph), Dominique P. Bureau (U of Guelph)
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Paul Blanchfield (DFO)

Sampling trout

The fate of farmed Rainbow Trout

The fate of farmed fish after escape from commercial aquaculture operations is an ecological concern that has not been examined in relation to the freshwater industry. The extent to which escaped fish might impact freshwater ecosystems is dependent upon their survival and distribution in the wild and these data are essential for risk assessments.

Over a period of two years, we released Rainbow Trout (*Oncorhynchus mykiss*) from two commercial aquaculture operations in the North Channel of Lake Huron to simulate small- and large-scale escape events. Before release into the wild, Rainbow Trout were tagged with either telemetry transmitters or external tags. Monitoring of telemetry fish allowed for determination of site fidelity and dispersal of escaped trout, while angler return data were used to estimate distribution, survival, and growth. Escaped farmed Rainbow Trout showed low attraction to the cage sites, but repeated visits to the farms by most fish suggest that likelihood of recapture after an escape event is possible. The major sources of mortality were angling and avian predation. The next phase of this research is to assess the potential risks that escaped Rainbow Trout may pose when at large in Lake Huron in an effort to contribute to the ongoing sustainable management of this industry.

Jul. 2006 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), North Wind Fisheries Ltd., Meeker's Aquaculture Canada Inc.
Project team: Paul Blanchfield (DFO), Doug Geiling (DFO), Tom Johnston, Kristen Patterson, Lori Tate, Chris Wilson, Dan Gloticheskie, Mike Meeker
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Paul Blanchfield (DFO)

Rainbow Trout in cage

Substituting vegetable oils for fish oil in Rainbow Trout feed

Dietary fats are a major source of energy for Rainbow Trout. Phospholipids and steroid components of body organs also rely on dietary lipids for synthesis, with certain fatty acids essential for health, growth, and normal appearance of the fish. Fish oils are the best sources of these essential fatty acids. However, the use of fish oils in finfish diets is expensive and its availability is expected to decline while demand continues to rise. This will result in an increase in feed prices and higher production costs. Furthermore, some studies have indicated that farmed salmon have significantly higher levels of persistent organic pollutants (POP) and heavy metals, compared to their wild counterparts. These contaminants are not biodegradable, and bioaccumulate and biomagnify through the food chain. At high levels, organochlorines have direct toxic effects and are carcinogenic and many are considered to be endocrine disrupters. Given that many persistent organic pollutants (POP) are liposoluble (fat soluable), nutritionists and feed manufacturers have directed research towards finding nutritionally-sound fish oil alternatives.

This proposed research project will develop Rainbow Trout diets that will partially replace fish oil with vegetable oil. This project will examine how the partial replacement of fish oil by various levels of vegetable oil will affect growth. Replicate tanks of trout will be fed to excess on a control diet (no vegetable oil) or diets that are otherwise identical but have increased levels of vegetable oil.

This study will provide the aquaculture industry with credible solutions to the issue of contamination levels in farmed salmonids. An additional advantage of fish oil replacement is the significant cost benefit to the aquaculture industry given the relatively low cost and enhanced sustainability of feeding vegetable oil.

Jul. 2009 – Jul. 2010 • Funded by: Martin Mills Inc., Elmira, Ontario Ministry of Food, Agriculture and Rural Affairs
Project team: Richard D. Moccia (U of Guelph), Michael Burke (U of Guelph), David Bevan (U of Guelph), Neil MacBeth (U of Guelph), Michael Kirk (U of Guelph), Mark Wagner (Martin Mills Inc.)
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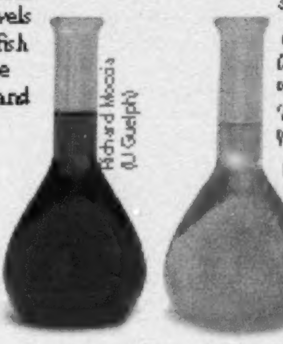
Genetic variation in Rainbow Trout

Understanding the genetic basis of trait variation remains an essential goal for the improvement of aquaculture strains worldwide. Research is currently ongoing towards inventorying the genetic variation in wild, semi-domesticated, and diploid and triploid strains of Rainbow Trout in British Columbia, and a commercial strain (i.e., the LYNDON strain of Rainbow Trout) in Ontario. This strain is one of the major egg producing strains in central Canada. Building a genetic database for the LYNDON strain will help in monitoring mating success and inbreeding, through pedigree identification. The database can also eventually be utilized to help in pre-selecting broodstock individuals for desired production traits within the strain. Studies are directed at identifying the genomic regions regulating production traits such as the timing of seasonal female ovulation, (i.e., increasing the egg production window), and the onset of male maturation schedules (i.e., decreasing the incidence of early maturation), in this strain. Through the application of molecular genetic technologies such as microarray gene expression analyses, and gene expression studies of specific genes regulating appetite, growth, and lipid metabolism in Rainbow Trout, knowledge will be obtained on specific genes regulating these performance traits. By incorporating this knowledge with information on the genomic locations of genes regulating the production traits (i.e., obtained from family-based QTL studies), it should be possible to identify the most specific candidate genes regulating the various production traits under study, and thereby enhance broodstock selection regimes.

Nov. 2008 – Nov. 2012 • Funded by: NSERC Strategic Grants Program, DFO – Canadian Regulatory System for Biotechnology (CRSB)
Project team: Sean Pressey (LYNDON Fish Hatcheries Ltd.), Lynn Rieck (LYNDON Fish Hatcheries Ltd.), Gord Cole (Aqua-Cage Fisheries Ltd.), Roy Danzmann (U of Guelph), Moira Ferguson (U of Guelph), Nick Bernier (U of Guelph), Bob Devlin (DFO), Michael Burke (Alma Aquaculture Research Station), Amber Garber (Huntsman Marine Sciences Centre), Bill Robertson (Huntsman Marine Sciences Centre), Melissa Allen, Jody Atkinson, Aaron Goldt, Andrea Kocmarek, Riley Magee, Colin Richardson, Cameron Richardson, Brendan Wringe, Hooman Moghadam, Anne Easton, Xia Yue
Contact: Roy Danzmann (rdanzman@uoguelph.ca)


Richard Moccia (U Guelph)

Herring and vegetable oil

Replacement of fish meal with soy in salmonid species

Increasing reliance on cost effective plant protein ingredients in fish feed formulation is considered key to the economical and environmental sustainability of salmonid culture operations. Many studies have shown that a large proportion of the fish meal in the diet of salmonids can be replaced with plant protein ingredients without deleterious effect on growth and feed efficiency of the animals. However, in other studies, incorporation of high levels of plant protein ingredients resulted in significant reductions in the feed intake, growth and/or feed efficiency of the fish. There is a need to develop a more comprehensive understanding of the nutritive value and limitations of plant protein ingredients and to better identify the sources of variations and inconsistencies amongst the results from feeding trials.

This project is based on the systematic analysis of results of scientific studies published over the past three decades on the replacement of fish meal by alternative protein sources in salmonid diets. Analysis of the results is based on two distinct approaches. The first approach involves a statistical meta-analysis of selected studies meeting strict selection criteria. The second approach involves analysis of results from a wide number of studies using a novel integrated nutritional model framework. The approach based on model simulation provided much greater flexibility to predict growth and nutrient utilization of fish fed a variety of diets formulated with different plant protein ingredients. This project suggests that the integrated nutritional model can be a useful tool to compare fish growth and utilization across various diets and ingredients. The model could also prove valuable to help fish feed manufacturers improve feed formulae.

May 2008 – Oct. 2010 • Funded by: United Soybean Board, USDA Fats and Proteins Research Foundation
Project team: Katheline Hua (U of Guelph), Dominique P. Bureau (U of Guelph)
Contact: Katheline Hua (khua@uoguelph.ca), Dominique P. Bureau (dbureau@uoguelph.ca)

Corn gluten meal and pigmentation of Rainbow Trout

Pigmentation is an important quality criterion for farmed salmonids. Dietary pink and red carotenoid pigments (astaxanthin and canthaxanthin) included in feeds contributes very significantly to the cost of production of farmed salmon and trout. Corn gluten meal (CGM) is a cost-effective protein-rich ingredient commonly used in salmonid fish feeds. However, this feedstuff contains high levels of yellow xanthophylls carotenoid (mainly lutein and zeaxanthin). Anecdotal evidence suggests that these xanthophyll carotenoids may negatively affect pigmentation of salmonid fish, either by imparting an undesirable yellowish hue to the flesh or by reducing efficiency of utilization of the expensive pink/red pigments incorporated in the diet.

The main objective of this research project is to develop a cost-effective approach to reduce the yellow carotenoid pigment content in CGM and to evaluate the effect of pigment-reduced CGM on flesh pigmentation of Rainbow Trout. The research project combines a series of bench-scale experiments to develop cost-effective pigment reduction techniques, the production of pigment-reduced CGM on a pilot-scale to produce significant quantity of this novel ingredient and its use in large-scale feeding trials with Rainbow Trout. The effect of yellow xanthophill carotenoids on efficiency of astaxanthin retention by Rainbow Trout will also be examined.

May 2006 – Aug. 2012 • Funded by: National Science and Engineering Council (NSERC), Ontario Ministry of Natural Resources
Project team: Patricio Saez (U of Guelph), Dominique P. Bureau (U of Guelph), Elsayed Abdelaal (AAFC), Jim Atkinson (U of Guelph)
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Disease resistance in Arctic Charr

As a species, Arctic Charr are a hardy fish with good overall disease resistance. However, the bacterial pathogen, Furunculosis (*Aeromonas salmonicida*), is a widespread problem that can result in significant losses to any fish farm. The objective of this project is to create a line of Arctic Charr with improved resistance to this disease.

Our first goal was to determine whether or not there is sufficient genetic variation for this trait in the Icy Waters strains to achieve measurable change. During the summers of 2008 and 2009, several unvaccinated populations of Arctic Charr were exposed to the pathogen, which is present in local sources of surface water. Differences in the mortality of the Tree River and the Nauyuk Lake strains demonstrated that genetic variation is indeed present in our populations and a selection program may be feasible. Survivors from this challenge continue to be maintained at our facility and form the core of our Furunculosis resistant line. They will be ready to spawn by the fall of 2011.

Our current objective is to estimate the heritability of resistance to Furunculosis for our Arctic Charr populations. As the program develops, we hope to identify genetic markers for resistance that can be incorporated into our marker-assisted selection program.

Apr. 2006 – ongoing • Funded by: Icy Waters Arctic Charr Ltd.
Project team: Colin McGowan (Icy Waters Arctic Charr Ltd.), Jonathan Lucas (Icy Waters Arctic Charr Ltd.), John Rose (Icy Waters Arctic Charr Ltd.)
Contact: Colin McGowan (cmcgowan@icywaters.com) • www.icywaters.com

Genetic variation associated with freshwater and brackish water growth performance in Arctic Charr

Many species of salmonid fishes are tolerant of being reared in full strength seawater once they have smoltified, due to their evolutionary adoption of a life-history cycle that involves anadromous migrations between freshwater and saltwater. Other species such as Arctic Charr have, however, lost this capability to a certain degree as they have become restricted to more freshwater habitats, or have only evolved to undergo more restricted migrations into estuarine environments. In fact, a great deal of variation is known to exist among different family lines of Arctic Charr in their capabilities to withstand a full seawater challenge. These observations clearly exemplify that different genes in the populations of these fish facilitate their survivorship. By investigating the genetic variation associated with growth performance in both freshwater and brackish water among full-sib families of Arctic Charr from the Shippagan strain, insights will be provided to investigators of the more important genomic regions regulating growth in this species in both environments. Identifying the genomic regions that permit survivorship and growth in full-strength seawater is also a target of the research being conducted, and this is being done using a pair of full-sib families to try and identify QTL regions within the genome of Arctic Charr that confer the greatest survivorship and growth in a seawater environment. The families selected for more detailed genetic analyses, were chosen based upon their performance upon entering seawater (i.e., with high variation in blood osmolality readings, and growth rates).

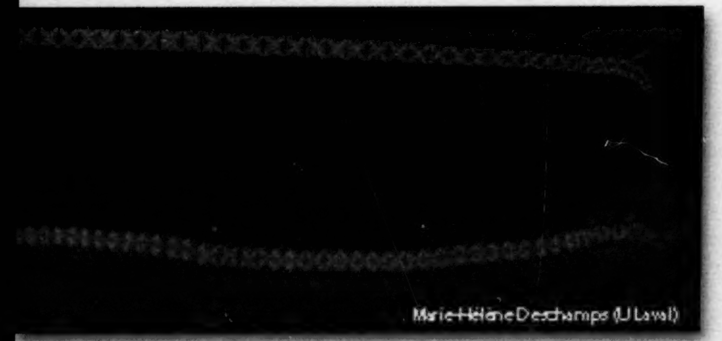
Coupled to the studies on growth performance in Canadian strains of Arctic Charr is an interest in comparing growth performance and understanding the underlying genetics of growth expression in Arctic Charr strains worldwide. Using a commercial strain of Arctic Charr from the Icelandic National Breeding program (i.e., of European ancestry), comparisons are being made of the growth-regulating QTL regions in this strain, to those identified in the Shippigan strain (i.e., derived from the Fraser strain of North American ancestry).

Nov. 2006 – Nov. 2010 • Funded by: NSERC Strategic Grants Program
Project team: Claude Pelletier (Coastal Zone Research Institute), Paul Merlin (CanAqua Seafoods Ltd.), Roy Danzmann (U of Guelph), Moira Ferguson (U of Guelph), Sebastien Plante (U of Moncton), Brian Glebe (DFO – SABS), Skuli Skulason (Holar University College, Iceland), Marcia Chiasson, Sarah Granier, Eva Kittner, Joe Norman, Xia Yue, Anne Easton • Contact: Moira Ferguson (mmfergus@uoguelph.ca)

Arctic Charr blood sampling

HARLEY-DAVIDSON

Moira Ferguson (U of Guelph)


Marie-Hélène Deschamps (U Laval)

Spinal cords of healthy Rainbow Trout (top) and phosphorus-deficient Rainbow Trout (bottom)

Expression of target genes in vertebral bone remodeling in farmed Rainbow Trout: effects of various dietary phosphorus levels

The development of new indicators of bone tissue metabolism is required to address many important concerns respecting aquaculture development (development of new feeds, strains with low phosphorus requirements, nutrient balance models, status of the physiological condition of fish, etc.) and specifically to gain a better understanding of the development of skeletal anomalies in intensive farming of salmonids.

Preliminary experiments presented at the annual meeting of RAQ in 2010 showed that a phosphorus-deficient diet induces multiple vertebral anomalies in farmed Rainbow Trout. The project now wishes to identify the regulatory mechanisms (role and function of genes) involved in bone tissue growth that lead to such observations. More specifically, we wish to qualify and quantify to a high level of detail the effects of various dietary phosphorus levels on vertebral growth and maintenance. A combined approach being employed uses genomics combined with physiological and histomorphological analyses.

This international research project (Canada, United States, France, Belgium, and Norway) involves the joint work of some fifteen researchers specialized in the fields of molecular biology, nutrition, fish tissue mineralization, and aquaculture.

Jan. 2011 – Dec. 2013 • Funded by: Ministère du Développement économique, de l'Innovation et de l'Exportation, DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Programme de recherche et de développement en aquaculture continentale (SORDAC) Inc., Réseau Aquaculture Québec (RAQ), Université Laval
Project team: Grant Vandenberg (U Laval), Marie-Hélène Deschamps (U Laval), Nadia Aubin-Horth (U Laval), Claude Robert (U Laval), Dominique Bureau (U Guelph), Ann Huysseune (Universiteit Gent, Belgique), Eckhard P. Witten (Universiteit Gent, Belgique), Jean-Yves Sire (Université Paris 6, France), Chantal Cahu (IFREMER, France), Dominique Mazurais (IFREMER, France), Kenneth Overturf (University of Idaho), Ron Hardy (University of Idaho), Tom Hansen (Havforskningsinstituttet, Norvège), Anna Wargelius (Havforskningsinstituttet, Norvège), P.E. Fjelldal (Havforskningsinstituttet, Norvège)
Contact: Grant Vandenberg (grant.vandenberg@fsaa.ulaval.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Rainbow Trout fecal settling characteristics

The physical characteristics of feed and fecal waste products from trout aquaculture are important in the development of improved effluent treatment methods. They are also important considerations for the regulatory control of "open" system technologies (e.g., cage farming), which is partially based on the dispersal characteristics of wastes in the receiving environment. The physical characteristics of greatest interest include the settling characteristics and size distribution of particles. These qualities provide the fundamentals for wastewater treatment in land-based aquaculture facilities and for the modelling of waste dispersion and the benthic "footprint" of cage-based aquaculture facilities.

An earlier study determined the physical characteristics of feed and fecal waste generated by 400 g rainbow trout fed three commercial diets. The present study expands the data set of fecal waste principle physical characteristics to include those produced by larger, market-sized Rainbow Trout approximately 1 kg. This study supports the contention that the fecal settling velocity for large Rainbow Trout (400 to 1200 g) is higher than generally recognised, with 50% of the mass settling at 5.9 cm s^{-1}.

Feb. 2010 – May 2010 • Funded by: Environment Canada (EC), Ontario Ministry of Food, Agriculture and Rural Affairs
Project team: Richard D. Moccia (U of Guelph), David Bevan (U of Guelph), Debbie Audet (EC)
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Zootechnical measures in commercial Arctic Charr aquaculture operations

The primary objective of our proposal is to implement innovative zootechnical measures that could have impact on productivity of commercial Arctic Charr aquaculture operations. The easy-to-implement measures are based on research applied to aquaculture conducted by the members of the scientific team associated with this proposal. This proposal has a research component involving technology transfer and commercial-scale validation. In our view, this proposal promotes the development of expertise in the industry and the creation of operational bases essential to growers to promote their integration and/or the initiation of a selection program for high-performance lines of Arctic Charr. The recommended measures are aimed at reproduction (spawner pairing) and nursery (velocity conditions) operations. The specific objectives are 1) to estimate the genetic variability of available the Nauyuk strain in Quebec for genetic improvement and a strain development program; 2) to identify the level of relatedness between spawners and optimal pairings/crosses; and 3) to implement variable velocity conditions to significantly improve growth and the early identification of the highest-performing families.

Sept. 2010 – 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Société de recherche et de développement en aquaculture continentale (SORDAC) Inc.
Project team: Nathalie R. Le François (Montréal Biodôme), France Dufresne (UQAR), Pierre U. Blier (UQAR), SORDAC, Francis Dupuis (Aquaculture Gaspésie inc.)
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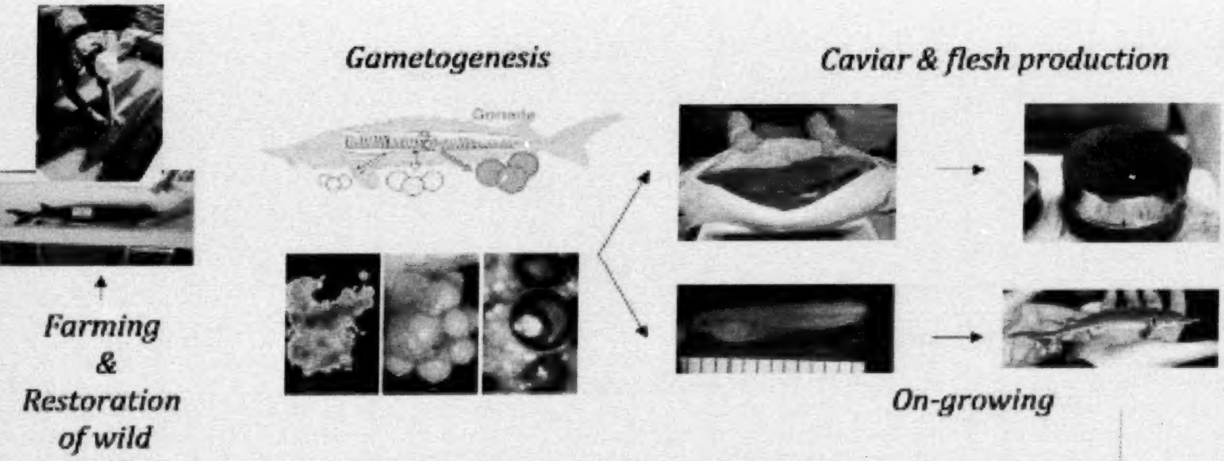

M.H. Deschamps

Scheme of sturgeon culture

From culture to conservation

A workshop to develop advanced reproductive technologies for sturgeon, May 8-9, 2010 Biodôme, Montréal

Novel non-invasive techniques for early sex identification in sturgeon has the promise of great economic value for current commercial aquaculture and the potential to be extremely useful in the protection and restoration of the remaining wild stocks. The objectives of the workshop were to review the current available methods in regard to all aspects of sex differentiation in sturgeons and to identify the R&D necessary to put in practice target methods. Several needs were identified during the workshop, but only nine major problems faced by the industry were chosen for prioritization. Results of the workshop were presented at *Aquaculture Canada 2010* and NAIA Cold Harvest 2010 and will be published in the proceedings of the congress. With the help of our new research group, a partnership with industry, conservation and academic researchers, we are now working on a literature review as well as on the elaboration of research proposals. Lake Sturgeon will be the subject of special attention because of its weak documentation and expressed interest by Québec private partners and institutions (native species that has no major legal constraints for sale in US, strong similarities with Shortnose Sturgeon, egg size, etc.).

Feb. 2010 – Mar. 2010 • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), DFO – Aquaculture Collaborative Research and Development Program (ACRDP), International Partnership for Sustainable Freshwater Aquaculture Development Inc (IPSFAD), Biodome de Montreal
Project team: N.R. Le François (Montreal Biodome/UQAR), G. Vandenberg (U Laval), M. Deschamps (U Laval), E. Boucher (IPSFAD),
J. Henry (Target Marine Products), B. Hogan (Supreme Sturgeon & Caviar), D. Breau (Supreme Sturgeon & Caviar), D. Farley (Quebec Caviar), J. Ehmarneh (Quebec Caviar)
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Characterization of waste generated by trout fed commercial feed currently used in Canada

nitrogen, phosphorous, solids

The commercial feeds formulated over the past decade have changed considerably and differ substantially from so-called conventional feeds. They are higher in digestible energy which means they have higher food efficiency, while producing less solid and soluble wastes.

The objective of this project is to accurately determine the growth coefficient and apparent digestibility coefficient of nitrogen and phosphorus for various size ranges of Rainbow Trout and Brook Trout fed different commercial feeds and exposed to two water temperatures (8 and 14°C). On the basis of the results, we will be able to establish nitrogen, phosphorus and dry matter balances.

These new coefficients may be used in the mathematical model developed by the University of Guelph Fish Nutrition Research Laboratory or by MAPAQ. The data will be used by the Canadian aquaculture industry to estimate the quantity of nutrients discharged by aquaculture enterprises and to properly assess the systems required to treat their effluent in order to reduce the industry's environmental footprint.

Dec. 2009 – Mar. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Société de recherche et de développement en aquaculture continentale (SORDAC) Inc., Programme d'aide à la recherche industrielle du Conseil national de recherches du Canada (PARI-CNRC)

Project team: G. Vandenberg (Interprovincial Partnership for the Sustainable Freshwater D.), E. Boucher (Interprovincial Partnership for the Sustainable Freshwater D.), E. Proulx (Laval University), D. Proulx (Laval University), A. Dube (Laval University), G. Ouellet (Ministère de l'agriculture, des pêcheries et de l'alimentation)
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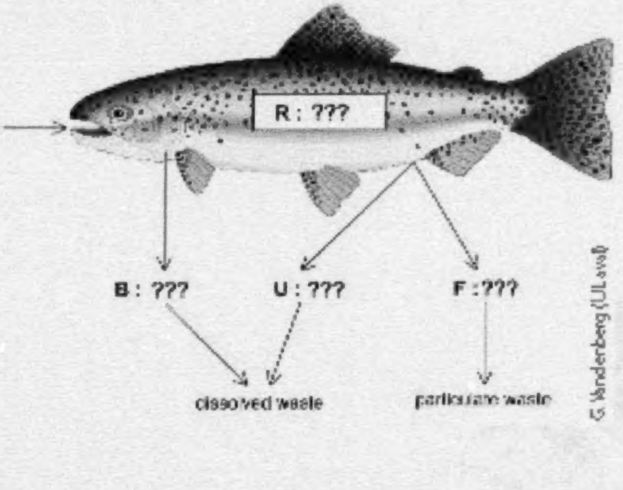
Rainbow Trout pathways of excretion



G. Vandenberg (U Laval)

Display of fresh trout for market MAPAQ

Certification standards for Rainbow Trout

Driven by consumers, seafood buyers and environmental groups, a number of international certification standards have emerged. To date, a clear leader has yet to be established amongst the leading initiatives (e.g., World Wildlife Fund (WWF), Global Gap, ISO, United Nations Food and Agriculture Aquaculture Certification Guidelines, etc.). Nevertheless, most initiatives have targeted the same issues, namely: farm-to-market product traceability, quality control, environmental sustainability, social sustainability, ethical production, etc. They are widely recognized as being essential to secure continued market access.

IPSFAD has recently taken the lead to investigate a national strategy for certification standards for freshwater Rainbow Trout in Canada. As such, IPSFAD sent a delegation of freshwater aquaculture stakeholders to participate in WWF's on-going consultation process and to use these discussions as a springboard to develop a strategic plan for certification within the Canadian freshwater rainbow trout sector. The work of the IPSFAD special committee was also to submit comments on behalf of IPSFAD members to assist the Freshwater Trout Aquaculture Dialogue's (FTAD) Steering Committee revise the FTAD draft standards for environmentally and socially responsible trout farming.

Sept. 2010 – Dec. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Interprovincial Partnership for the Sustainable Freshwater Aquaculture Development Inc., Northern Ontario Aquaculture Association
Project team: Grant Vandenberg (Interprovincial Partnership for the Sustainable Freshwater Aquaculture Development Inc.), Eric Boucher (Interprovincial Partnership for the Sustainable Freshwater Aquaculture Development Inc.), Jeff Eastman (Manitoba Agriculture, Food and Rural Initiatives), Karen Tracey (Northern Ontario Aquaculture Association), Mike Meekers (Northern Ontario Aquaculture Association), Dean Foss (Wild West Steelhead), Mike Rose (Global Trust), Sylvain Lareau (Association des Aquaculteurs du Quebec) • Contact: Grant Vandenberg (grant.vandenberg@fsaa.ulaval.ca)

Production of all-female stocks of Arctic Charr of the Fraser strain at the Coastal Zones Research Institute

Early sexual maturation in male Arctic Charr is considered a serious constraint to the commercialization of our Fraser-Shippagan strain. A project was therefore developed to produce all-female stocks. The Coastal Zones Research Institute acted as advisor to the Fisheries and Oceans Canada and to the industry partner (Merlin's Fish Farm) in collaboration with the University of Guelph. The approach used in our study is indirect feminization. In the first feeding, future broodstock was fed feed containing the male sex hormone 17α-methyldihydrotestosterone (MDHT). The neomales thus obtained will be crossed with normal females when they reach sexual maturity.

The use of phenotypic markers will be used to determine the sex of the individuals. All individuals of each experimental family will be genotyped for these same markers. We will then be able to identify and separate neomales from females on the basis of their genotype within the experimental families. This project should allow us to produce all-female stocks.

Apr. 2009 – Mar. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), New Brunswick Department of Agriculture, Aquaculture and Fisheries, Coastal Zones Research Institute, Merlin's Fish Farm
Project team: Brian Glebe (DFO – SABS), Claude S. Pelletier (CZRI), Paul Merlin (Merlin's Fish Farm), Moira Ferguson (U of Guelph), Marcia Chiasson (U of Guelph), Tillmann Benfey (UNB), Christophe Herbinger (U of Dalhousie)
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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/projects/projects-eng.asp

Phase-feeding of dietary phosphorus in Rainbow Trout to reduce phosphorus discharges

Intensive aquaculture operations can result in phosphorus loadings in the environment, contributing to eutrophication of sensitive receiving waters. Phosphorus discharges from fish farms can be reduced by directly altering the bioavailability of this nutrient and the composition of fish feeds. The primary objective of this project was to optimize the formulation of a phosphorus-deficient diet. The second objective was to identify the alternating pattern of phosphorus-deficient and phosphorus-sufficient diets that maximizes growth in Rainbow Trout and minimizes phosphorus discharges. Now that the alternating pattern has been identified, the third objective is commercial-scale testing of this feeding regime. The final objective is to validate the development of this regime and its commercial use through a feasibility study. The results of this project will contribute directly to the sustainable development of the Canadian aquaculture industry. This type of feeding regime could be a tool for helping fish producers meet the objectives set by the Quebec Environment Department (STRADDAQ).

Sept. 2006 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Société de recherche et de développement en aquaculture continentale (SORDAC) Inc., Fonds québécois de la recherche sur la nature et les technologies (FQRNT), Réseau Aquaculture Québec (RAQ), Programme d'aide à la recherche industrielle du Conseil national de recherches du Canada (PARI-CNRC)
Project team: Grant Vandenberg (Interprovincial Partnership for the Sustainable Freshwater Aquaculture Development inc.), Johanie Fournier (Laval University), Eric Boucher (Interprovincial Partnership for the Sustainable Freshwater Aquaculture Development inc.), Rémy Lambert (Laval University), Joël de la Noüe (Laval University), Emilie Proulx (Laval University), Daniel Proulx (Laval University), Normand Roy (Ferme piscicole des Bobines), Dave Snow (Corey Feed Mills Ltd.), Clément Roy (Ferme piscicole des Bobines)
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Evaluation of a shrimp by-product to replace fishmeal in diets of Arctic Charr and other salmonids

A series of studies will be conducted at the Coastal Zones Research Institute (CZRI) to improve cost effectiveness of current and alternative sources of beneficial nutrients in aquafeeds. The objective of the first study is to evaluate a shrimp by-product available in Atlantic Canada in diets of Arctic Charr at an early life history stage. The shrimp by-product contains high concentrations of nutrients found in fishmeal (e.g., amino acids, omega-3, vitamin E, cholesterol, phospholipids, astaxanthin). One positive control diet is formulated to mimic a commercial trout feed. Five other treatment feeds contain 30, 20, 10, 5 and 0% herring meal with graded levels of shrimp by-product to replace the fishmeal on a digestible amino acid basis. Arctic Charr will be obtained from the CZRI stock and allocated to thirty 800-L circular tanks. At the end of the trial, rates of amino acid and lipid deposition will be measured to describe the efficiency of utilization of nutrients for growth and determine the cost effectiveness of the shrimp by-product. Other studies will focus on: (1) evaluating alternative sources of dietary nutrients from raw materials available in Atlantic Canada; and (2) optimizing fishmeal inclusion levels based on its composition and the fish life history stage.

Jan. 2011 – May 2011 • Funded by: Department of Agriculture, Aquaculture and Fisheries of New Brunswick, Regional Development Corporation of New Brunswick, New Brunswick Innovation Foundation
Project team: André Dumas (CZRI), Rémy Haché (CZRI), Yves Hébert (CZRI), Claude Landry (CZRI) • Contact: André Dumas (andre.dumas@irzc.umcs.ca)

Multifactorial selection (growth and disease resistance) and genetic improvement of pure and domestic Brook Trout strains: implementation of a program on farmed fish genetics

Brook Trout is the most important freshwater aquaculture species in Quebec. A group of Quebec aquaculture growers associated with the Centre de Transfert et de Sélection des Salmonidés inc. (CTSS) pooled resources to launch a genetic improvement program focused on two traits, growth and absence of early sexual maturation. The project resulted in the production of disease-free spawners of known origin, for both the Rupert and domestic strains, allowing the continuation of the work. Genetic analysis of the spawners was conducted to assess genetic diversity and to perform high-performance matings while avoiding inbreeding. The results obtained show the high inter-individual and interfamily variability required to develop a selection program. For example, depending on family, the rate of male early sexual maturation ranges from 0 to 100%. It is also interesting to note that all Spearman correlations performed on domestic strains are significant, which means that regardless of the culture site, the highest performing families show a strong tendency to be the same, even in the case of the least high-performing families.

Nov. 2007 – Mar. 2010 • Funded by: MAPAQ, Société de recherche et de développement en aquaculture continentale (SORDAC) inc., Société de développement de l'industrie maricole (SODIM), CREGIM, DEC
Project team: Luc Picard (CTSS), François Lavigne (CTSS), Louis Bernatchez (U Laval), Guillaume Côté (U Laval), Dany Proteau (P. Lac-St-François), Michel Fournier (P. Denis Fournier), Jacques Roy (P.J. Roy), Mario Demers (MRNF), Éric Hamelin (A Nordik), Marco Blanchet (P. Trois-Lacs), Céline Audet (UQAR)
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Claude S. Pelletier (CZRI)

Arctic Charr

Underwater image of a Brook Trout

Eric Engbretson (U.S. Fish and Wildlife Service)

Arctic Charr at CZRI CZRI

Arctic Charr swimming depth preferences and feeding behaviour in seawater cages

Wild anadromous Arctic Charr *(Salvelinus alpinus)* migrate to seawater for up to eight weeks between June and September, where they can grow rapidly, and then return to freshwater for the long winter. Given the high growth rate at sea and the species' ability to withstand cold temperatures, Arctic Charr appears to be an ideal candidate for salt water culture in Atlantic Canada in general and Newfoundland in particular. Nonetheless, conflicting results have been obtained regarding seawater rearing of Arctic Charr with data suggesting that fish general performance is highly strain dependent. Recent trials by the industry partner in this project suggest that three strains (Nauyak, Labrador, and hybrids between Three Rivers and Nauyak) of Arctic Charr have been successfully reared in seawater in the summer with satisfactory growth. Moreover, most strains survived the harsh local winter conditions with mortalities lower than 0.5% per month. However, issues have been observed in feeding behaviour (surface and bottom feeders) as well as appropriate depth for feed distribution. These observations raise a number of questions on preferred depths for feeding and fish swimming patterns in the cages. This project proposes to monitor fish movement in sea cages to determine potential differences in feeding patterns between strains. Moreover, there is a need to understand environmental conditions in cages and how these parameters may influence fish swimming patterns. This will be achieved by deploying sondes in the cages and monitoring fish movement using hydroacoustic techniques. Ensuring feed is given at the appropriate depth to avoid stressing fish by unnecessary exposure to high surface temperatures is also one of the goals of gathering information on fish distribution in cages.

Apr. 2010 – Apr. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Nordic Salmon Co. Inc.
Project team: Dounia Hamoutene (DFO), Chris Lang (DFO), Lee Sheppard (DFO), Sharon Kenny (DFO), Dwight Drover (DFO), John and Brian Nealey (Nordic Salmon Co. Inc.)
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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Arctic Charr cage culture

Dounia Hamoutene (DFO)

Breeding program for Arctic Charr *(Salvelinus alpinus)* of the Fraser strain

An Arctic Charr breeding program has been under way at the Coastal Zones Research Institute (CZRI) since 1996. The main objective of the program, which is today based on modern molecular biology techniques, is to promote Arctic Charr aquaculture by offering growers a competitive and high-performance product. The research is designed to control inbreeding and improve the zootechnical performance of broodstock and its offspring. Since the start of the project, Dr. Christophe Herbinger, a geneticist at Dalhousie University in Halifax, has served as scientific advisor for our program. The growth gains achieved to date are over 40% relative to the first generation. The eggs of the fifth generation were obtained in the fall of 2010 at CZRI and, once hatched, their zootechnical performance will continue to be closely monitored until they reach commercial size. A software program integrating the genetic information of the individuals selected was created to ensure continuity of our program. With some degree of adaptation, the software can be applied to the genetic improvement of other species.

1996 – ongoing • Funded by: Ministry of Agriculture, Aquaculture and Fisheries of New Brunswick, Atlantic Canada Opportunities Agency, Coastal Zones Research Institute
Project team: Claude S. Pelletier (IRZC), André Dumas (IRZC), Christophe Herbinger (Dalhousie U), Joël Cormier (IRZC), Gilles David (IRZC), Claude Landry (IRZC), Philippe Fullsack (Dalhousie U)
Contact: Claude S. Pelletier (claudes.pelletier@irzc.umcs.ca)

Testing the effectiveness of the SuperSmolt® Program to reduce stress and mortalities associated with the introduction of juvenile Rainbow (Steelhead) Trout *(Oncorhynchus mykiss)* to full strength sea water marine grow out sites

The main objective of this Aquaculture and Fisheries Research Initiative Inc. project was to assess the effectiveness of the SuperSmolt® Program treatment system at acclimating trout for entry into full strength sea water.

The SuperSmolt® Program was developed specifically as a treatment to control smoltification in Atlantic Salmon. This project tested the program with Rainbow (Steelhead) Trout, grown in a freshwater re-circulating system at the Brookvale hatchery in PEI and transferred to two marine grow-out sites in Nova Scotia.

The program was applied to a selected batch of juvenile trout over a 42 day period. Due to water temperature issues at one of the cage sites, some tanks were held on the program for a further 11 days, which meant they were not included in the final project results.

Overall the mortality levels at introduction were reduced, down to roughly 5-10%, from 15-25% in previous years.

Apr. 2010 – Aug. 2010 • Funded by: Aquaculture and Fisheries Research Initiative Inc.
Project team: Shaun MacLeod, Peter Warris, PEI Aquaculture Alliance, Ocean Trout Farms Inc.
Contact: Shaun MacLeod (smacleod@coldwaterfisheries.com)

Control of post-harvest myoliquefaction in farmed Atlantic Salmon

Soft-flesh syndrome presents a significant challenge to the fish-farming industry by compromising product quality and lending to a negative consumer stigma of farmed fish products. In farm-reared Atlantic Salmon *(Salmo salar)* the most common cause of soft-flesh is a parasitic infection by *Kudoa thyrsites*. At the moment, there are no available treatments to control *K. thyrsites* infection. Alternative technologies, such as high hydrostatic pressure (HHP) have been successful at controlling parasite infestation in other meat processing industries. In this project an industrial trial using HHP technology was tested as a means to control the manifestation of myoliquefaction caused by *K. thyrsites* infection. Whole fish and fillets were subjected to several pressure intensities, which were applied for different times. Myoliquefaction manifestation (presence and number of pits formation) was monitored daily for 5 consecutive days. Fish fillet quality parameters such as colour, texture, flesh integrity (gaping), and smell were evaluated in pressure treated and untreated fillet portions using standard operation procedures for quality control. The results demonstrated that the HHP technology was not effective at suppressing myoliquefaction, and it adversely affected product quality, including colour and texture.

July 2009 – Mar. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Marine Harvest Canada
Project team: Diane Morrison (Marine Harvest Canada), Luis Afonso (BC-Centre for Aquatic Health Sciences – BC-CAHS), Alexandra Eaves (BC-CAHS), Stewart Johnson (DFO – PBS), Tiffany MacWilliam (AHC)
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Atlantic Salmon genome sequencing

Genome BC has partnered with the Chilean Economic Development Agency "InnovaChile", the Norwegian Research Council, and the Norwegian Fishery and Aquaculture Industry Research Fund to sequence the Atlantic Salmon genome. Access to a well-annotated salmon genome will directly benefit the world's fisheries and aquaculture industries. The multi-phased project's goal is to produce a genome sequence that identifies and maps the genes in the Atlantic Salmon genome. This genome will then act as a reference and guide sequencing of the genomes of other salmonids, including Pacific salmon and Rainbow Trout, and more distantly related fish such as smelt and pike. Unlike the human and mouse genome sequencing projects, the Atlantic Salmon genome sequence will not be considered a "finished" sequence. The quality of the Atlantic Salmon sequence will be critical as it must be of sufficient quality to support detailed analyses, such as comparisons of duplicated regions within the genome and comparative genomics involving other fish species. The sequence will be used for the population management of wild fish stocks, food security and traceability, conservation of populations at risk and broodstock selection for commercially important traits.

Nov. 2009 – ongoing • Funded by: Genome British Columbia, The Research Council of Norway, The Norwegian Fishery and Aquaculture Industry Research Fund, The Chilean Economic Development Agency (CORFO), InnovaChile Committee
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www.genomebc.ca/partners/international-collaborators/international-cooperation-to-sequence-the-atlantic-salmon-genome/

BC-CAHS

Whole Atlantic Salmon being loaded into the colander

Discovery Passage plankton monitoring and juvenile salmon assessment

This collaborative research partnership is monitoring phytoplankton and zooplankton levels in the Northern Georgia Strait to determine optimal release dates for juvenile enhanced Coho Salmon with a goal of improving their survival. The project, which just completed its fourth year of data collection, is facilitated by the BC Centre for Aquatic Health Sciences (BC CAHS) in partnership with the Fisheries and Oceans Canada's Quinsam River Hatchery and the A-tlegay Fisheries Society.

Availability of food following hatchery release is crucial to the early survival of salmon. Through this project, BC CAHS and its partners are developing monitoring tools that will be used to establish the best time to release juvenile coho based on maximum productivity in the nearshore environment. The project's initial goal was to increase coho survival and subsequent returns to the Campbell and Quinsam Rivers (at the Quinsam Hatchery survival of enhanced coho had dropped from highs of 8-10% in the 1980s to less than 1%). The knowledge gained from this project can be applied to other enhancement hatchery facilities and river systems and can be adapted to the specific needs of other Pacific salmonids.

Annual reports for previous project years are available on the BC CAHS website.

Jan. 2010 – Dec. 2010 • Funded by: Campbell River Salmon Foundation, Aboriginal Fisheries Society, Positive Aquaculture Awareness, Marine Harvest Canada, City of Campbell River, the Campbell River and District Fishing Guides Association
Project team: Sonja Saksida (BC CAHS), Brian Downey (BC CAHS), Alexandra Eaves (BC CAHS), Shannon Anderson (DFO), Dave Ewart (Quinsam River Hatchery), Ken Duncan (A-tlegay Fisheries Society) • Contact: Sonja Saksida (sonja.saksida@cahs-bc.ca) • www.cahs-bc.ca

BC-CAHS

Setting up for a plankton tow

Wild salmon Genome BC

Flesh quality of farmed and wild salmon from British Columbia

In January of 2004, a highly publicized study indicated that farmed Atlantic Salmon collected from supermarkets around the globe contained higher levels of lipophilic organohalogen contaminants (e.g., polychlorinated biphenyls (PCBs), and polychlorinated dibenzodioxins and furans (PCDD/Fs)) than wild salmon. Although the levels of contaminants in farmed Atlantic Salmon flesh were not a human health concern according to various national food safety regulatory guidelines, importation of farmed Atlantic Salmon to the United States decreased by 20% in the first quarter of 2004 due to public concerns over the adverse effects of these contaminants. Globally, demand for farmed products decreased despite the fact that many studies had shown positive effects of frequent fish consumption on cognitive development and reduced risk for some types of cancer, inflammatory diseases and coronary heart disease. Health benefits are enhanced by the consumption of oily fish such as salmon that are high in omega-3 highly unsaturated fatty acids (n-3 HUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). However, positive health benefits of an oily fish diet may be compromised by negative effects associated with the occurrence of contaminant residues such as PCBs, PCDD/Fs, pesticides, flame retardants, as well as mercury (Hg), lead (Pb), cadmium (Cd), and other trace metals.

This study investigated the presence of environmental contaminants (PCBs, PCDD/Fs, pesticides, PBDEs, mercury, and all trace elements) in the flesh of three species of farmed salmon and five species of wild salmon from coastal British Columbia (BC). The study provides information regarding current contaminant levels in the flesh of farmed and wild BC salmon and also examined the contaminants associated risks to benefits associated with the human consumption of salmon containing high amounts of DHA and EPA. Our findings indicate that current flesh levels of major contaminants that include trace metals such as Hg, Arsenic (As) and Cd and organohalogens (PCBs, PCDD/Fs) in farmed and wild salmon from BC are below the recommended levels of concern for human health. Thus, weekly consumption of BC salmon products that originate from farmed and wild sources is an excellent and safe way to obtain adequate dietary intake of n-3 HUFAs for cardio-protective and other human health benefits.

2003 - 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), AquaNet, BC Salmon Farmers Association BC Science Council, and the former Federal Office of the Commissioner for Aquaculture Development
Project team: Michael G. Ikonomou (DFO), David A. Higgs (DFO – CAER), Keng Pee Ang (Cooke Aquaculture Inc.), Shannon Balfry (DFO – UBC), Cory Dubetz (DFO)
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New feeds dramatically reduce POPs in farmed salmon flesh

The high lipid content in farmed salmon diets (≤ 40%), traditionally provided primarily by marine fish oil (MFO), enhances the deposition of lipids and lipophilic persistent organic pollutants (POPs), found in MFO, relative to levels that are found in wild Pacific salmon. Nevertheless, the levels of POPs (e.g., polychlorinated biphenyl compounds (PCBs) and polychlorinated dibenzodioxins and furans (PCDD/Fs) in farmed salmon flesh are not a human health concern according to the US Food and Drug Administration and Health Canada guidelines. In recent years, several studies have been published which outline concerns associated with the consumption of fish containing high levels of contaminants, POPs, and heavy metals in particular. Yet there are a limited number of studies which link the contaminant-associated risks to the benefits related to the consumption of salmon, an excellent source of omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

The potential for using new diet formulations based on terrestrial lipids (TL), derived from a variety of plants (e.g., oilseeds such as soybeans and canola), and animal products (poultry fat), was investigated as a major replacement for MFOs in commercial salmon feeds. These alternate diets contained up to 65% lower ∑PCB concentrations compared to traditional diets containing MFOs. Utilization of these diets resulted in dramatic reductions in the concentrations of POPs in the flesh of the farmed salmon. For example, farm-raised Atlantic and Chinook Salmon fed the alternative lipid-based diets (i.e., 50% poultry fat or 35% canola oil), exhibited PCB and PCDD/F flesh concentrations that were 48 to 60% lower than those found for fish fed the traditional diets. Moreover, flesh TEQ (toxic equivalent concentrations with respect to 2,3,7,8-TCDD) levels in farm-raised salmon fed the alternative TL-based diets were found to be equivalent to or lower than those in wild Pacific salmon.

In the flesh of farmed Atlantic Salmon fed the alternative TL-based diets, levels of the omega-3 fatty acids DHA and EPA were up to 50% lower than those observed in farmed Atlantic Salmon fed the traditional diets but were still greater than those found in wild Pacific salmon. This study also showed that the recommended intake of 250 $\text{mg} \cdot \text{d}^{-1}$ of EPA and DHA for humans can be achieved by eating two 100 g servings of farmed Atlantic Salmon each week. In contrast, this same daily intake of EPA and DHA would require either larger proportion sizes of wild Pacific salmon or more frequent servings from these sources each week.

2005 - 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), BC Salmon Farmers Association, BC Science Council, the former Federal Office of the Commissioner for Aquaculture Development
Project team: Michael G. Ikonomou (DFO – IOS), Erin N. Friesen (UBC), David A. Higgs (DFO – CAER), Keng Pee Ang (Cooke Aquaculture Inc.), Cory Dubetz (DFO – IOS)
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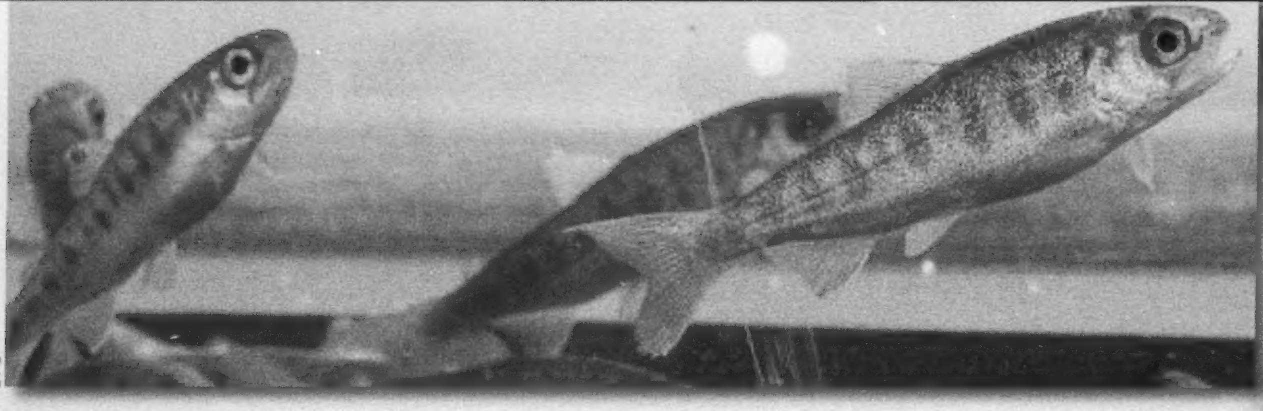

DFO

Early life stage salinity tolerance of wild and hatchery-reared juvenile Pink Salmon

Salinity tolerance in wild (Glendale) and hatchery (Quinsam) Pink Salmon *Oncorhynchus gorbuscha* (average mass 0.2 g) was assessed by measuring whole body sodium $[Na^+]$ and chloride $[Cl^-]$ concentration after 24 or 72 h exposures to freshwater (FW) and 33, 66 or 100% seawater (SW). Gill Na^+, potassium $[K^+]$-ATPase activity was measured following exposure to FW and 100% SW and increased significantly in both populations after a 24 h exposure to 100% SW. Whole body $[Na^+]$ and whole body $[Cl^-]$ increased significantly in both populations after 24 h in 33, 66 and 100% SW, where whole body $[Cl^-]$ differed significantly between Quinsam and Glendale populations. Extending the seawater exposure to 72 h resulted in no further increases in whole body $[Na^+]$ and whole body $[Cl^-]$ at any salinity, but there was more variability among the responses of the two populations. Percent whole body water (c. 81%) was maintained in all groups of fish regardless of salinity exposure or population, indicating that the increase in whole body ion levels may have been related to maintaining water balance as no mortality was observed in this study. Thus, both wild and hatchery juvenile *O. gorbuscha* tolerated abrupt salinity changes, which triggered an increase in gill Na^+, K^+-ATPase within 24 h. These results were also discussed in terms of the preparedness of emerging *O. gorbuscha* for the marine phase of their life cycle.

Feb. 2007 – Mar. 2011 • Funded by: British Columbia Pacific Salmon Forum, Natural Sciences and Engineering Research Council of Canada (NSERC)
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Growth and ionoregulatory ontogeny of wild and hatchery-raised juvenile Pink Salmon

Juvenile Pink Salmon (*Oncorhynchus gorbuscha*) enter seawater (SW) shortly following emergence. Little is known about growth and development during this life-history stage when sensitivity to sea louse exposure may be high, an issue that is of current concern in British Columbia. We tested the hypothesis that growth and ionoregulatory development were similar in hatchery-raised (Quinsam) and wild (Glendale and One's Point) juvenile Pink Salmon (measured over 22 weeks) followed by SW entry. Fish body mass increased from 0.20 ± 0.01 to 6.47 ± 0.37 g, with mean specific growth rates of 2.74% to 3.05% body mass·day^{-1} among the three groups. In all three groups, gill Na^+-K^+-ATPase (NKA) activity peaked at 12 μmol ADP·mg $protein^{-1}$·h^{-1} following 8 weeks post-transfer to SW. Whole body Na^+ and Cl^- concentrations, which again did not differ among groups, were highest upon initial exposure to SW (approximately 70 mmol·kg wet $mass^{-1}$) and declined over time as gill NKA activity increased, indicating that the hypo-osmoregulatory capacity was not fully developed following emergence and initial entry into SW. Thus, consistent with our hypothesis, few differences were observed between hatchery-raised and wild juvenile Pink Salmon reared under laboratory conditions. These baseline data may be important for future studies in determining the effects of sea lice on wild juvenile Pink Salmon.

Sept. 2009 – Apr. 2012 • Funded by: British Columbia Pacific Salmon Forum, Natural Sciences and Engineering Research Council of Canada (NSERC)
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Swimming performance and associated ionic disturbance of juvenile Pink Salmon determined using different acceleration profiles

Swimming performance was assessed in juvenile Pink Salmon, *Oncorhynchus gorbuscha*, (body mass < 5.0 g) using five different protocols: four constant acceleration tests each with a different acceleration profile (rates of 0.005, 0.011, 0.021 and 0.053 cm s^{-2}) and a repeated ramped-critical swimming speed test. Regardless of the swim protocol, the final swimming speeds did not differ significantly ($P > 0.05$) among swim tests and ranged from 4.54 to 5.20 body lengths s^{-1}. This result supports the hypothesis that at an early life stage, *O. gorbuscha* display the same fatigue speeds independent of the swimming test utilized. Whole body and plasma $[Na^+]$ and $[Cl^-]$ measured at the conclusion of these tests were significantly elevated when compared with control values ($P < 0.05$) and appear to be predominantly associated with dehydration rather than net ion gain. Given this finding for a small salmonid, estimates of swim performance can be accurately measured with acceleration tests lasting < 10 min, allowing a more rapid processing than is possible with a longer critical swim speed test.

Feb. 2007 – Mar. 2011 • Funded by: British Columbia Pacific Salmon Forum, Natural Sciences and Engineering Research Council of Canada (NSERC)
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Atlantic Salmon sampling Steve Leadbeater (DFO – SABS)

Genomic selection and association mapping of Atlantic Salmon populations

Aquaculture now produces all the Atlantic Salmon consumed by Canadians and a significant amount for export. However, disease in marine farmed stock is a major constraint affecting the sustainability and profitability of this industry. Disease has a direct impact on farm income through lost production and treatment costs and an indirect impact by influencing consumer demand. Fortunately the rate of genetic improvement for difficult traits such as disease resistance might be greatly improved by using a new method of animal breeding called genomic selection. We are using 5000 SNP genetic markers to determine which of the offspring produced by a disease-resistant family have inherited the disease-resistant alleles. We are testing whether genomic selection can improve growth rate in saltwater, rapid adaptation to seawater, disease resistance and delayed sexual maturity more rapidly than the conventional breeding program currently used at Cooke Aquaculture Inc. in New Brunswick. We will accomplish this within 3 years by using DNA samples and estimated breeding values archived over a four year period from past broodstock and their relatives, as well as the performance of their harvested siblings in seawater farm cages. We can then predict if greater genetic changes in these traits would accrue from genomic selection.

Oct. 2009 – Sept. 2012 • Funded by: NSERC Strategic Project Grant
Project team: Elizabeth Boulding (U of Guelph), Larry R. Schaeffer (U of Guelph), Anne Tosh (U of Guelph), Patricia T. Schulte (UBC), Keng P. Ang (Cooke Aquaculture Inc.), Alli Burton (Cooke Aquaculture Inc.), Jake Elliott (Cooke Aquaculture Inc.), Brian Glebe (DFO – SABS), Steve Leadbeater (DFO – SABS), Patrick O'Reilly (DFO – BIO), Bill Wolters (USDA, Maine)
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Salmon yearlings

Ted Sweeten (DFO – PBS)

Study investigates historical and social dimensions of salmon aquaculture science

Salmon aquaculture has been a focus of environmental research for over two decades. This project is applying the tools of environmental history and science and technology studies to understand how this research has developed, and the roles it has played in public discussions regarding the industry. Several more specific objectives are also being pursued.

First, an environmental history of salmon aquaculture science is being written. This history will explore the relations between scientific research and the evolving environmental, social, and political dimensions of the industry. Second, the project is examining how the diverse institutions engaged in environmental research – governments, universities, industry and public interest organizations – have shaped research priorities, research results, and the application of these results. Third, the movement of scientific knowledge of salmon aquaculture between research sites in Canada, Norway, Ireland, and Scotland is being investigated. Fourth, the project is investigating the prospects for effective science that is able to contribute to resolution of controversies regarding this industry. While this project is examining the full range of environmental science relating to salmon aquaculture, a special focus is on research relating to sea lice.

Jun. 2007 – Jul. 2011 • Funded by: Social Sciences and Humanities Research Council of Canada, Genome BC
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Determination of global gene expression patterns in Atlantic Salmon (*Salmo salar*) fed with novel fish feed ingredients

Seafood transformation and processing plants produce large amounts of commercially marketable products each year, however, an appreciable amount of by-products are discarded or transformed in fish meal. These marine by-products contain valuable amounts of proteins, lipid fractions, vitamins or other bioactive molecules having potential beneficial properties that could be used in human or animal nutrition.

As part of a larger study looking at the development and commercialization of marine by-products for use in animal and human nutrition and its application to the prevention of human diseases, this specific study aims to evaluate the potential health benefit and growth effects in Atlantic Salmon fed with novel fish feed formulations each supplemented with a specific marine by-product. For this purpose, DNA microarrays will be used to measure the global gene expression response and to look at the specific gene response in various targeted pathways such as oxidative stress, inflammation, immunity, lipid metabolism and others, in an attempt to identify the most promising marine by-products. Results obtained will be correlated with digestibility data from another study being done in parallel and fish feed formulation showing the most interesting results will be further studied at the physiological level.

Jan. 2010 – Sept. 2011 • Funded by: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund, Institut de recherche sur les zones côtières inc. (IRZC)
Project team: Sebastien Plante (IRZC), Francis LeBlanc (DFO), Mark Laflamme (DFO), Nellie Gagné (DFO), France Béland (IRZC), Sebastien Plante (UMCS), Jacques Gagnon (IRZC), Nadia Tchoukanova (IRZC)
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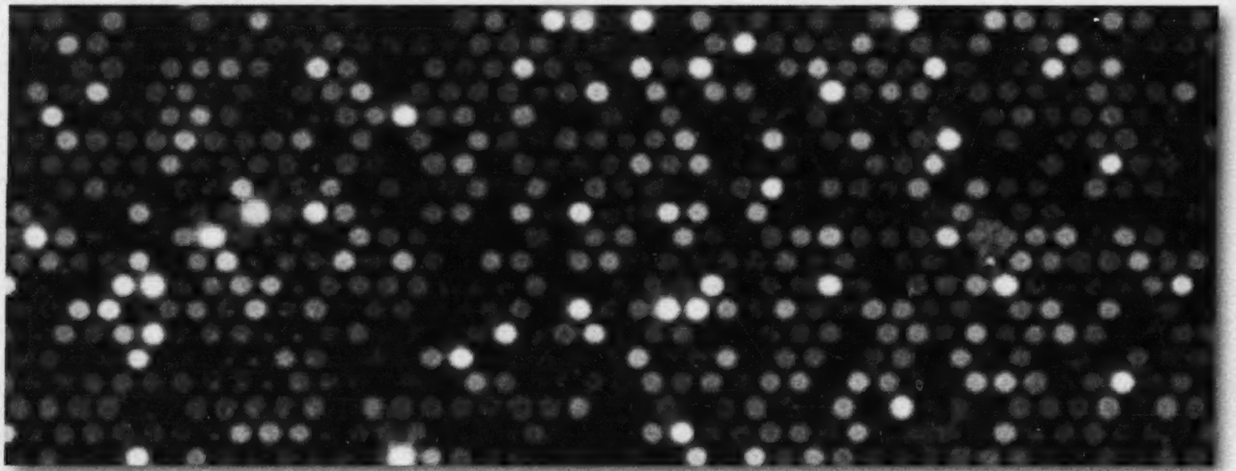

Juvenile microarray image Francis LeBlanc (DFO)

Transcriptional response comparison of naturally immunized ISAV resistant Atlantic Salmon and naïve Atlantic Salmon challenged with a highly virulent ISAV isolate

Following an infection with a specific pathogen, the acquired immune system of many teleostean fish, including salmonids, is known to retain a specific memory of that agent, which protects the host against a subsequent infection. For example, Atlantic Salmon that survive an infection from a low-virulent infectious salmon anemia virus (ISAV) isolate are protected against a subsequent infection with a highly virulent ISAV isolate. An understanding of the mechanisms and immunity components involved in this acquired protection against ISAV is fundamental for the development of efficacious vaccines and treatments against this pathogen. Thus, in an attempt to better understand the immunity components involved in the observed resistance, we have used an Atlantic Salmon DNA microarray and qRT-PCR assays to study the global gene expression responses of naturally immunized Atlantic Salmon during the course of a new infection with a highly virulent ISAV isolate. Global gene expression patterns in immunized fish versus that of naïve fish, following infection by either cohabitation with infected fish or by direct intra-peritoneal injection of the virus will be studied. The results obtained from this study will greatly enrich our already acquired knowledge on ISAV-Atlantic Salmon interactions and could be useful in the creation of novel vaccines and treatments.

Apr. 2008 – Mar. 2011 • Funded by: DFO – Genomics Research and Development Initiative (GRDI)
Project team: Francis LeBlanc (DFO), Jean-René Arseneau (DFO), Brian Glebe (DFO – SABS), Steven Leadbeater (DFO – SABS), Mark Laflamme (DFO), Nellie Gagné (DFO)
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Phototherapy: applications for growth enhancement and maturation delay in farmed Bay of Fundy Atlantic Salmon *(Salmo salar)*

Maturation (grilsing) rates in farmed salmon steadily increased from less than 1% in 1978 (average among the first salmon farms) to greater than 30% at some farming sites in 2001. This change resulted in significantly reduced farm gate sales and prompted the industry to give high priority to research into methods to decrease grilsing.

In 2001, the first Aquaculture Collaborative Research and Development Program (ACRDP) funded study on the effect of artificial photoperiod on grilsing rates was initiated at two commercial salmon farms. A group of cages had submerged lights turned on in November. A second set of cages had lights turned on in February. Lights were left on 24 hours per day. All lights were turned off in May. Additional cages, exposed to only natural photoperiod, served as controls. During the first month, specific growth rates decreased in the November-lit cages. However, by the end of May, November-lit cages showed significantly higher growth rates than the control cages. At the first farm, an average of only 1% of the salmon in the November-lit cages matured compared to 11% and 21% of the fish in the February-lit and -unlit control cages, respectively. On the second farm, 5% of the salmon from October-lit cages matured compared to 17.5% in the unlit control cages.

An economic benefit analysis of the improved growth and delayed maturation due to the use of an artificial photoperiod showed a saving of up to $100,000 per cage (based on the November photoperiod adjustment and assuming a cost of lighting equipment purchase and operation of $5,000 per cage).

A recent follow-up of an ACRDP study involving four farms, confirmed the effectiveness of light treatment for reducing grilsing in salmon and a more cost-effective artificial lighting regime was developed. Also, an ELISA biomarker, developed for this project, was shown to be valuable for assessing photoperiod regime effectiveness during critical periods of maturation onset in salmon.

Apr. 2009 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Jail Island Salmon, Cooke Aquaculture Inc.
Project team: Brian Glebe (DFO – SABS), Tony Manning (Research and Productivity Council), Keng P. Ang (Cooke Aquaculture Inc.)
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Wolf eels Jonathan Wong

Sustainable culture development for Wolf Eels

Adult Wolf Eel (*Anarrhichthys ocellatus*) breeding pairs (out-crossed brood years 1995 and 2001) located at the Vancouver Aquarium and the DFO – Centre for Aquaculture and Environmental Research, had histories of producing unfertilized eggs. In each of these years and at both sites, the females appeared to be ovulating and releasing normal eggs. Therefore the cause of these unsuccessful fertilizations was attributed to the males not being fully mature. This past spawning season, (2009-2010) the male Wolf Eels located at each site were implanted with Ovaplant™ (Syndel Laboratories Ltd., BC) two weeks prior to when spawning had occurred in previous years. Within 7-10 days post-implantation, each pair had successfully produced a large, cohesive egg mass of ca. 15,000 eggs. The egg masses were incubated in the laboratory inside a high-flow venturi incubator under ambient water conditions. The fry hatched within 3 months, and were immediately feeding on artificial diets. Juveniles are currently involved in diet and density studies. In summary, the development of various incubation and husbandry techniques demonstrate that Wolf Eels can be successfully bred and reared in captivity. Implications of these results are of interest for use in culturing Wolf Eels for the live market food industry.

Apr. 2009 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Island Scallops Limited
Project team: Shannon Balfry (CAER), Steve Macdonald (DFO – CAER), Jeff Marliave (UBC); Rob Saunders (Island Scallops Ltd.)
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Sablefish genomics: understanding genetic variation in Sablefish

The Sablefish industry is a $300 million a year industry in North America and an important emerging fish stock for British Columbia. While commercial demand is rapidly increasing, wild stocks are remaining stable. There is a need for genetic tools to facilitate establishment of a successful Sablefish aquaculture as well as to enable better management of wild fish stocks.

Funded by Genome BC, the Sablefish Genomics project developed a preliminary suite of genomic tools that can provide important information to both aquaculture companies and management of wild fish stocks. University of Victoria's Ben Koop, in collaboration with Sablefish Canada Ltd, identified and characterized the genetic variation in Sablefish, allowing for efficient identification of individuals for monitoring wild stocks as well as for selective breeding programs for aquaculture. The preliminary characterization of genetic markers in Sablefish has led to the development of genomic tools for general gene expression analysis, thereby facilitating fisheries to specifically select for genes that are associated with growth, reproductive success and traits that will help make Sablefish aquaculture a sustainable and profitable industry for British Columbia.

Jan. 2009 – Mar. 2010 • Funded by: Genome British Columbia, Sablefish Canada Ltd., University of Victoria
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Stress resistance selection and better growth in Atlantic Cod

One of the sub-projects of the Atlantic Cod Genomics and Broodstock Development Project (CGP) investigated whether families of Atlantic Cod vary in the magnitude of their cortisol stress response. For this study, fish (30) from each family (10) were measured, weighed and PIT-tagged, and then subjected to a standardized handling stressor (20s out of the water) which was applied once a month for 5 consecutive months. At the end of the study fish within each family were classified as consistent high cortisol responders (HR), low cortisol responders (LR), or non-consistent responders (NC). The proportion of the LR and HR phenotypes varied greatly between families. In addition, body mass, SGR and condition factor were significantly higher in LR when compared with HR fish; average LR fish body mass was 345.1 g and HR fish was 221.8 g at the end of the experiment. These results indicate that responsiveness to stress (based on cortisol levels) may be an important trait to consider in a broodstock development program.

Aug. 2005 – Sept. 2007 • Funded by: Genome Canada, Genome Atlantic, the Atlantic Canada Opportunities Agency (ACOA) through the CGP
Project team: Kurt Gamperl (MUN-OSC), Tiago Hori (MUN-OSC), Luis O.B. Afonso (BC-CAHS), Matthew L. Rise (MUN-OSC), Stewart Johnson (DFO – PBS)
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Sablefish Ted Sweeten (DFO – PBS)

Sablefish nutrition

Sablefish (*Anoplopoma fimbria*), also known as Black Cod, have been sustainably harvested in BC for many years, but high demand has resulted in the recent establishment of a small culture industry.

A growth trial was conducted at the DFO – Centre for Aquaculture and Environmental Research (CAER) in West Vancouver to provide information about the optimum dietary combination of protein, lipid, and carbohydrate required for growth and feeding efficiency.

A hallmark of this species is the very high fat content of the flesh, which is responsible for the soft buttery texture of the meat that is highly desirable to consumers. It is expected that best performance will be achieved on a high fat diet. As Sablefish are carnivores, it is expected that they require a high protein diet.

The fish were fed for 11 weeks and exhibited excellent growth rates, indicating that the experimental conditions and protocols were suitable.

One interesting aspect of this research was that it was run as a mixture experiment, which is ideal for studies investigating how multiple dietary ingredients work together to affect a response variable (typically growth or feed efficiency). The findings are still being collated, but it is evident that juvenile Sablefish require high protein and fish oil for optimum growth.

Sept. 2010 – Dec. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Sablefish Canada
Project team: Ian Forster (DFO – CAER), Briony Campbell (Sablefish Canada), Jamie Bridge (Sablefish Canada)
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Mixture methodology for studying diet formulations in fish aquafeed research

Modern feeds for fish reared under intensive conditions, (e.g., salmon), are very efficient at meeting the nutritional needs of the fish while minimizing waste production. This efficiency has been achieved by applying the results of extensive research conducted using modern methods of nutritional science. Mixture methodology is a relatively new research approach to identifying optimum combinations of ingredients. In mixture experiments, combinations of specific test ingredients are combined in a series of feeds in a defined way, such that they sum to a fixed proportion of the feeds, while the remaining portion of each feed is held constant. The response (usually growth or feed efficiency) of the animals fed these feeds is then monitored. Mixture methodology assumes that the observed response is a function of the proportions of the ingredients tested. Using this methodology, relationships between ingredients or nutrients can be ascertained and optimum combinations identified. Mixture experiments can test combinations of multiple components using fewer resources (fish, tanks and labour) than factorial methods. Mixture experiments may be used to find feed protein and energy levels that maximize growth or to identify combinations of ingredients that meet the nutritional needs of fish for the least cost.

Sept. 2010 – Dec. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Sablefish Canada
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The forgotten sex: paternal effects on embryonic and larval mortality of Atlantic Cod

It is important to understand parental effects on early life history of fish as manifested, for example, in individual fitness of offspring. Immediately after fertilization, parental contributions (genetic and non-genetic) to embryos will affect larval ontogeny, physiology, morphology and survival. In marine fish, rates of natural mortality are highest during early life and are negatively correlated with rates of growth and body size. In these early life stages (eggs, larvae, young juveniles) subtle differences in mortality can cause large differences in recruitment and year-class success. Therefore, it is particularly critical to understand factors that contribute to variability in mortality during early life. This study focuses on evaluating the potential influence paternity has on rates of mortality and development in eggs and larvae of Atlantic Cod (*Gadus morhua*). Paternity had a strong influence on mortality during the early embryonic phases for progeny of one female, whereas early embryonic mortalities of the other female were largely maternally induced. Mortalities stabilized after day 6 (end of gastrulation), with hatching success ranging from 8 to 65% for progeny of one female and nearly zero for the other. Therefore, mate choice during spawning can play a large role on offspring survivorship (fitness).

May 2009 – Apr. 2010 • Funded by: EU COST-funded Short Term Scientific Mission (STSM) in "Fish Reproduction and Fisheries" action (FRESH; FA0801)
Project team: Marie H.M. Kroll (Hamburg University, Germany), Myron A. Peck (Hamburg University, Germany), Ed Trippel (DFO – SABS)
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Anarhichas minor

Growth trial of the Spotted Wolffish in pre-commercial conditions

Numerous studies have been done on the development of wolffish aquaculture in Québec, Canada. This project puts together all the recent knowledge by Canadian, Norwegian and Icelandic research groups on a full cycle production with the objective of maximizing growth performance (density, optimal temperature-at-size, feed/feeding). Another objective will be to fully evaluate the profitability of wolffish cultivation in Québec, Canada.

2008 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Société de développement de l'industrie maricole (SODIM), MAPAQ
Project team: Nathalie R. Le François (Montreal Biodôme/UQAR), Denis Chabot (DFO – IML), France Dufresne (UQAR), SODIM, MAPAQ
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Effects of extended photoperiods and light intensities on growth, sexual maturation and tissue water content of Atlantic Cod in sea cages

Mariculture of Atlantic Cod (*Gadus morhua*) in the Bay of Fundy was initiated in the early 2000s and early puberty has been a persistent problem since its inception. The objectives of the present study were to evaluate, over separate two-year periods, whether 20 and 24 h light exposure compared to natural photoperiod in sea cages will (i) increase body growth, (ii) halt or delay sexual maturation, and (iii) affect seasonal levels of water content in muscle and liver tissue of Atlantic Cod. A positive growth response to extended daylength (20 and 24 h light) was observed, although these light treatments did not influence the incidence of sexual maturation of either sex. Greater light intensity also did not reduce the incidence of maturity. The proportion of fish sampled that were mature was often >50%. Immature cod of each gender were reported to grow at slower rates than mature cod. Implementation of extended daylength did, however, result in delaying attainment of sexual maturation by approximately 3 months. Of particular note is the lower reproductive investment (i.e., female GSI values) observed after two years of 20 h daily illumination. The percent water content of muscle tissue of adult females was greater than of immature females. Our results suggest the use of extended daylength to improve growth and change the timing and investment in reproduction holds some promise for Atlantic Cod mariculture.

May 2007 – Mar. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Cooke Aquaculture Inc.
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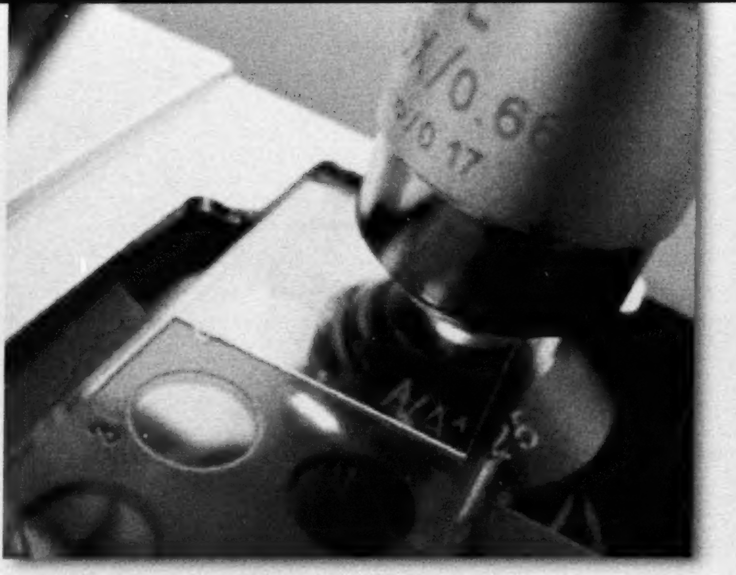

Measuring sperm motility Ian Butts (U of Windsor)

Gadus morhua

Cryopreservation of Atlantic Cod spermatozoa

Effects of extender composition and freezing rate on sperm motility, velocity and morphology

Broodstock selection programs are currently underway for Atlantic Cod (*Gadus morhua*). To complement and further these selection programs we need to develop sperm cryopreservation procedures. This will allow genomic DNA from males from selected individuals or stocks to be frozen and conserved in perpetuity. In our study we examined the effects of diluent (Mounib's sucrose-based diluent, Hanks' Balanced Salt Solution, Mounib's sucrose-based diluent + hen's egg yolk, and Hanks' Balanced Salt Solution + hen's egg yolk), cryoprotectant (propylene glycol, dimethyl sulphoxide, and glycerol), and freezing rate (-2.5, -5.0, -7.5, and -10.0°C/min) on motility of cod frozen-thawed sperm. Sperm velocity and morphometric analyses of sperm heads and flagella were also assessed. We found that sperm motility recovery index was strongly influenced by the presence of higher-order interactions of the factors we tested. The best cryoprotection used diluents that contained hen's egg yolk. Generally, extenders containing propylene glycol yielded higher post-thaw sperm motilities than those with dimethyl sulphoxide or glycerol. In comparison to sperm from other frozen-thawed extenders, sperm from extenders supplemented with propylene glycol had significantly higher curvilinear velocity. Cryopreservation showed no impact on sperm head morphology parameters; however, considerable damage to frozen/thawed sperm flagella was observed. We believe that our experimental/statistical approach and results add significantly new information to the study of semen biology/cryobiology in fishes. Our findings are also highly relevant to the development of cod mariculture and for aiding in conservation efforts of this very important marine species.

Jan. 2007 – Dec. 2010 • Funded by: Genome Canada, Genome Atlantic, Atlantic Canada Opportunities Agency, NSERC, Marguerite and Murray Vaughan Graduate Fellowship. A complete list of supporting partners can be found at www.codgene.ca/partners.php
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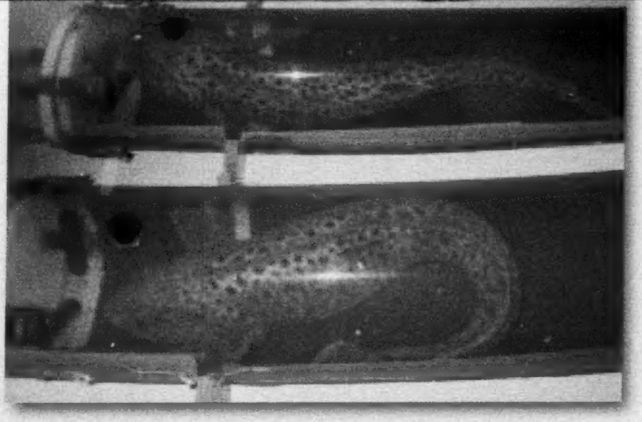

Impact of dissolved oxygen on survival, growth, and metabolism of the Spotted Wolffish

The main objectives of this project were to measure hypoxia tolerance of Spotted Wolffish using two different methods, the critical oxygen threshold or PO_{2crit} and the LC_{50} after 96 h of exposure, and the impact of chronic, sublethal hypoxia on growth of Spotted Wolffish and the hybrid Spotted x Atlantic Wolffish.

Spotted Wolffish in respirometers Martin Jetté (DFO)

Spotted Wolffish are tolerant of reduced oxygen down to about 26% air saturation ($LC_{05,96h}$), below which, the mortality risk becomes significant. Our two measures of lethal threshold were similar (PO_{2crit}: 16.8%; $CL_{50,96h}$ = 21% air saturation). However, higher levels of dissolved oxygen (DO) still have negative effects on wolffish growth, with growth significantly reduced at 40% air saturation. Growth was also reduced at 50 and 60% air saturation, but the reduction was not significant due to small sample sizes. A follow-up study with larger sample sizes is presently underway. Final analyses will include survival times at different low dissolved oxygen levels to ensure that the impact of equipment failure can be assessed. Our final results will also include a comparison of growth and hypoxia tolerance for the Spotted Wolffish and the hybrid wolffish.

Apr. 2009 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Société de Développement de l'Industrie Maricole, Université du Québec à Rimouski (UQAR), Montréal Biodôme
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Researchers strive for single-sex stocks of cultured Atlantic Cod

Atlantic Cod *(Gadus morhua)* has been selected as a potential candidate for aquaculture in Canada and internationally. However, early maturation and release of viable embryos from spawning fish in cages are major impediments to commercial viability and environmental stewardship. For these reasons, protocols to produce single-sex populations of cod are being developed to take advantage of sex-related differences in growth performance, prevent the release of fertilized eggs into the wild and aid in the development of all-female triploid (sterile) cod stocks.

Gynogenetic cod juveniles have been produced to identify the genetic mechanism of sex determination in this species. Gynogenesis is a process whereby expression of the paternal genome in viable embryos is prevented. If gynogenetic offspring are all females, then female is the homogametic sex, as in salmonids and Atlantic Halibut. Knowing the genetic basis of sex determination identifies the appropriate endocrine approach for producing single-sex populations.

Direct endocrine sex-reversal experiments were done to create broodstock capable of generating single-sex progeny. For example, if female Atlantic Cod are homogametic then all-female populations can be produced by first masculinizing genotypic females and then crossing these "neomales" with normal females to yield all-female offspring.

These techniques, as well as sex-reversed broodstock capable of generating single-sex stocks for commercial production, will be transferred to Canadian aquaculture companies to increase production performance and environmental sustainability.

Dec. 2008 – Dec. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Natural Sciences and Engineering Research Council of Canada (NSERC), New Brunswick Innovation Foundation (NBIF)
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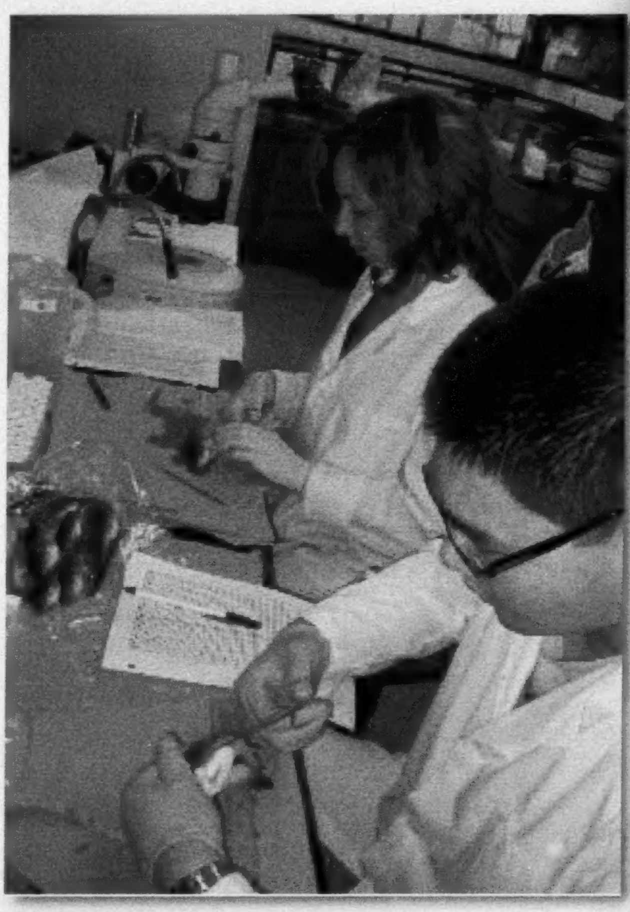

Atlantic Cod sex control D. Martin-Robichaud (DFO – SABS)

Hormonal induction of ovulation and spermiation in Atlantic Cod

Captive, wild-caught female Atlantic Cod *(Gadus morhua)* from Georges Bank were divided into three treatment groups based on body weight and diameter of the largest clutch of oocytes present. Treatments administered were an intramuscular implant of one of two gonadotropin releasing-hormone analogues (D-Ala6, Pro9-NHEt)-LHRH ethylamide (LHRHa, 150 µg) and salmon gonadotropin releasing-hormone analogue (sGnRHa, 150 µg, Ovaplant®), or a saline injection (control). Over a period of 20 days, 12 of the 14 implanted and one control fish ovulated. There was no significant variation between egg volumes and percent fertilization of implant-treated and naturally ovulating females; however, significant variation did exist for the estimated number of hatched larvae among treatments. Non-spermiating captive wild-caught Atlantic Cod males were divided into two treatment groups (Ovaplant® and saline control) based on body weight. Large volumes of milt with high motility and spermatocrits were obtained from each of five Ovaplant®-treated males starting 6 days post implant. Over a 27 day period, each of six control males produced milt at least once, but in small volumes with variable motility and low spermatocrits. Milt volumes of the Ovaplant®-treated males were higher than naturally spermiating males (P = 0.0002), but had similar motilities and spermatocrits. These results demonstrate the effectiveness of GnRHa implants in inducing ovulation and spermiation in Atlantic Cod broodstock without adversely affecting gamete quality.

2007-2009 • Funded by: Genome Canada, Genome Atlantic, Atlantic Canada Opportunities Agency, the Atlantic Marine Aquaculture Center, New Hampshire Agriculture Experiment Station, New Hampshire SeaGrant program
Project team: Amber Garber (Huntsman Marine Science Centre, SABS), Susan Fordham (Huntsman Marine Science Centre), Jane Symonds (National Institute of Water and Atmospheric Research Ltd., New Zealand), Edward Trippel (DFO – SABS), David Berlinsky (University of New Hampshire, USA)
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Amber Garber (HMSC)

Collection of milt from Atlantic Cod

Impact of food deprivation on growth response and activity of juvenile Atlantic Cod

Compensatory growth is a period of accelerated growth experienced by organisms encountering abundant food after a period of partial or total deprivation. Rates during compensatory growth exceed those of continuously fed fish and indicate that fish normally do not grow at the maximum rates which are physiologically possible. It is suggested that hyperphagia is the main mechanism involved in the compensatory growth response and it is often accompanied by increased growth efficiency. Identifying the mechanisms and dynamics of compensatory growth in marine fishes has practical applications to aquaculture production as it might help to design optimal feeding schedules, increase feeding efficiency and decrease environmental nitrogen loading. This study examined if juvenile Atlantic Cod exhibit a compensatory growth response after different types of food deprivation (single bout or periodic) and also attempted to link this physiological response to behavioural aspects, i.e., changes in locomotory activity before and after a period of food shortage. Juvenile cod experiencing 3 weeks of food deprivation exhibited higher specific growth rates. Gross growth efficiency of previously deprived fish was higher during re-alimentation than of control fish, although they could not catch up completely in size with continuously fed fish after the completion of the experiment. Activity of juveniles differed between day and night time and were a function of type of food deprivation. The findings indicate that partial growth compensation is possible for juvenile cod and suggest that activity is directly related to feeding level. Using the advantages of compensatory growth might help to reduce production costs and to minimize environmental impacts.

May 2009 – Apr. 2010 • Funded by: EU COST-funded Short Term Scientific Mission (STSM) in "Fish Reproduction and Fisheries"-action (FRESH; FA0601)
Project team: Ed Trippel (DFO – SABS), Maja Walter (Institute of Hydrobiology and Fisheries Science, Germany), Myron Peck (Institute of Hydrobiology and Fisheries Science, Germany) • Contact: Ed Trippel (Ed.Trippel@dfo-mpo.gc.ca)

The Atlantic Cod Genomics and Broodstock Development Project

The $18.1 million Atlantic Cod Genomics and Broodstock Development Project (CGP) aimed to develop a breeding program and fundamental genomics tools to supply the developing Atlantic Cod aquaculture industry in Canada with improved broodstock. Family-based breeding programs were initiated in Newfoundland and Labrador and New Brunswick, ensuring that local stocks were used for the benefit of industry partners. CGP data suggests that the breeding programs will be highly successful at improving growth rates, as well as other related traits such as fillet yield. Genetic variation was also found in stress response, thermal tolerance and disease resistance traits. Little variation was measured in sexual maturation or fillet quality at harvest.

The CGP dramatically improved genomic resources for this species, contributing 85.8% of publicly available DNA sequence information for Atlantic Cod. Over 100,000 genomic markers were identified and made available in GenBank. A genetic map was developed to help identify quantitative trait loci (QTL) related to key production traits such as growth, disease resistance and resistance to stress from handling. A microarray or "cod chip" was developed and used in several studies related to tissue response and early development. A combination of microarray and DNA sequence data aided selection of genes to include in genetic mapping and allowed for comparative genomics to identify possible candidate genes within QTL intervals. The genomics research coupled with breeding program data will help the cod industry continue to select fish with specific marker sequences rather than measuring and selecting based on individual fish phenotypes.

Jan. 2006 – Sept. 2010 • Funded by: Genome Atlantic, The Atlantic Genome Centre (TAGC), Huntsman Marine Science Centre, Atlantic Canada Opportunities Agency – Atlantic Innovation Fund, Newfoundland and Labrador Department of Fisheries and Aquaculture, DFO – Aquaculture Collaborative Research and Development Program (ACRDP), DFO – SABS, NRC – IMB, The New Brunswick Innovation Foundation, New Brunswick, Newfoundland and Labrador, Nova Scotia, Memorial University of Newfoundland Ocean Sciences Centre, University of British Columbia, University of Guelph, University of New Brunswick, Cooke Aquaculture Inc., Great Bay Aquaculture, Newfoundland Cod Broodstock Company, The Newfoundland Aquaculture Industry Association, Northern Cod Ventures, RPC – The Technical Solutions Centre
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Milt collection from Atlantic Cod Ian Butts (U of Windsor)

Semen characteristics and their ability to predict sperm cryopreservation potential of Atlantic Cod

There is a lack of biomarkers or indices that can be used to predict the quality of fish semen samples following the freezing and thawing cycle. In this study, we tested a series of semen indices to assess if they could accurately forecast the cryopreservation potential of Atlantic Cod semen. Fresh and frozen-thawed sperm activity variables were compared and relationships between frozen-thawed sperm activity and fertilization success were examined. In comparison with fresh sperm, our results clearly show that activity variables of cryopreserved spermatozoa are reduced. Of the 18 males examined, mean (± SEM) spermatocrit was 40.7 ± 4.23%, osmolality of the seminal plasma was 366.3 ± 4.95 mOsmol kg^{-1}, pH 8.3 ± 0.04, protein concentration was 1.1 ± 0.08 mg mL^{-1}, anti-trypsin activity was 153.8 ± 19.25 uL^{-1}, and total antioxidant capacity was 0.2 ± 0.03 µmol Trolox equivalents mL^{-1}. Fertilization success was highly variable among males with values ranging from 18.5 to 90.2%. Regressions demonstrated significant positive relationships between frozen-thawed motility, velocity, track crossing frequency, and subsequent fertilization success. Sequential multiple regressions explained up to 95% of the variation in frozen-thawed sperm activity. Spermatocrit and pH were negatively related, while osmolality and antioxidant capacity were positively related to frozen-thawed motility and velocity. Each of these indices can be measured within minutes of collecting a fresh sample of semen and are thus early indicators of the capacity of semen samples to withstand cryopreservation. These results have many benefits for conservation of wild stocks, aquaculture production, and for understanding semen biology and cryobiology of fishes.

Jan. 2009 – Dec. 2010 • Funded by: Research Council of Norway, Polish Academy of Sciences, the Natural Sciences and Engineering Research Council of Canada, Dr. John S. Little International Study Fellowship, Marguerite and Murray Vaughan Graduate Fellowship, Genome Canada, Genome Atlantic, Atlantic Canada Opportunities Agency
Project team: Ian A.E. Butts (DFO – SABS, UNB – now U of Windsor), I. Babiak (Bodø University College, Norway), A. Ciereszko (Polish Academy of Sciences, Poland), M. Litvak (UNB), M. Słowińska (Polish Academy of Sciences, Poland), C. Soler (University of Valencia, Spain), E. Trippel (DFO – SABS)
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Competitive spawning success and fertility of triploid male Atlantic Cod

Farmed Atlantic Cod *(Gadus morhua)* have been hypothesized to pose a risk to the natural environment through escape of fish or release of their gametes from sea cages. The use of sterile triploids has been suggested as a way to prevent spawning of farmed fish, whether escaped from their cages or still contained within them. This laboratory study examined the reproductive potential of triploid male Atlantic Cod, both *in vivo* and *in vitro*. We demonstrated that triploid males in competitive, size-matched mating with diploid males were successful at siring young. Spermatozoa produced by triploid males were larger than those of diploids, but did not differ in swimming velocity or ability to fertilize eggs. Hatch and larval survival rates, however, were reduced for progeny of triploid males. These diagnostic characteristics of aneuploidy suggest that although farmed triploid male cod may compete successfully with wild diploids for spawning access to wild females, their offspring will not survive.

Apr. 2008 – Dec. 2010 • Funded by: NSERC
Project team: Nathaniel Feindel (UNB/DFO – SABS), Tillmann Benfey (UNB), Ed Trippel (DFO – SABS) • Contact: Ed Trippel (Ed.Trippel@dfo-mpo.gc.ca)

Gonadal development of triploid Atlantic Cod

Atlantic Cod *(Gadus morhua)* is a prime candidate for marine finfish aquaculture diversification, but there are a number of problems associated with its culture that are constraining the advancement of the industry. Generation of sterile Atlantic Cod by the induction of triploidy is one technique being studied to address issues associated with early puberty. The aim of this study was to examine gonadal development of adult-aged, triploid Atlantic Cod prior to and during the annual spawning season in comparison to sibling diploids. Cod were sacrificed three times: prior to spawning, and during two subsequent spawning seasons (at age 3 and 4 years). Female triploid Atlantic Cod exhibited diminished ovarian development which was illustrated at both macroscopic and microscopic levels. Significant differences occurred between diploid and triploid female gonadosomatic indices during all three sampling periods and carcass yields during the two spawning periods. In contrast, testicular development of diploid and triploid Atlantic Cod was indistinguishable through macroscopic and histological assessment. No significant differences were found in male gonadosomatic indices or head-on gutted carcass yields in relation to ploidy, with the exception of a slightly higher carcass yield for triploid males during the spawning season. As a result of suppressed oogenesis, female more so than male triploid cod have the potential to be utilized and advance the development of the cod aquaculture industry.

May 2009 – Dec. 2010 • Funded by: NSERC
Project team: Nathaniel Feindel (UNB/DFO – SABS), Tillmann Benfey (UNB), Ed Trippel (DFO – SABS) • Contact: Ed Trippel (Ed.Trippel@dfo-mpo.gc.ca)

Atlantic Cod DFO

Seminal plasma biochemistry and spermatozoa characteristics of wild and cultivated Atlantic Cod

Our objectives were to compare spermatozoa activity, morphology, and seminal plasma biochemistry between wild and cultivated Atlantic Cod *(Gadus morhua)*. Swimming velocities of wild cod spermatozoa were significantly faster than those of cultivated males. Wild males had a significantly larger spermatozoa (i.e., the moving sperm cell) head area, perimeter, and length, while cultivated males had more circular heads. Total monounsaturated fatty acids and the ratio of n-3/n-6 fatty acids were significantly higher in sperm from wild males, while total n-6 from cultivated males was significantly higher than of wild males. Significantly higher concentrations of the fatty acids C14:0, C16:1n-7, C18:4n-3, C20:1n-11, C20:1n-9, C20:4n-3, C22:1n-11, and C22:6n-3 were observed in wild males, while significantly higher concentrations of C18:2n-6, C20:2n-6, and C22:5n-3 occurred in cultivated males. Osmolality, protein concentration, lactate dehydrogenase and superoxide dismutase activity of seminal plasma of wild males were significantly higher than of cultivated males. Antioxidant capacity of seminal plasma was significantly higher in cultivated males, while pH and anti-trypsin did not differ between fish origin. Four bands of anti-trypsin activity and nine protein bands were detected in seminal plasma. Performing a discriminant function analysis, on morphology and fatty acid data showed significant discrimination between wild and cultivated fish. Results are relevant to breeding programs and aquaculture development.

Jan. 2009 – Dec. 2010 • Funded by: Research Council of Norway, Polish Academy of Sciences, Natural Sciences and Engineering Research Council of Canada, Dr. John S. Little International Study Fellowship, Marguerite and Murray Vaughan Graduate Fellowship, Atlantic Cod Genomics and Broodstock Development Project.

Project team: Ian A.E. Butts (DFO – SABS, UNB now U of Windsor), I. Babiak, (Bodø University College, Norway), A. Ciereszko (Polish Academy of Sciences, Poland), M. Litvak (UNB), M. Słowińska (Polish Academy of Sciences, Poland), C. Soler (University of Valencia, Spain), E. Trippel (DFO – SABS), S.M.H. Alavi (University of South Bohemia, Czech Republic) • Contact: Ian Butts (iana.e.butts@gmail.com)
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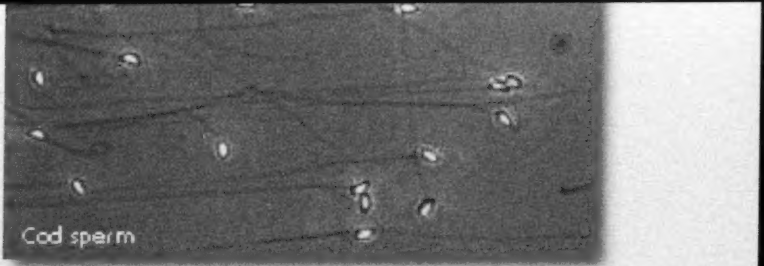
Ian Butts (U of Windsor)
Cod sperm

Cryopreservation of Atlantic Cod sperm in large volume straws: applications for commercial production and gene banking

In our study we used a full factorial ANOVA design to examine the effects of diluent (Mounib's sucrose-based diluent + hen's egg yolk, and Hanks' Balanced Salt Solution + EY), freezing rate (-2.5, -5.0, and -7.5°C min^{-1}), and thawing rate (2.5, 5.0, and 7.5°C min^{-1}) on motility and velocity of Atlantic Cod sperm cryopreserved in 2.5 mL cryogenic straws. We found that post-thaw sperm performance was strongly influenced by the presence of higher-order interactions of the factors we tested. For all models broken down by diluent, the 2.5°C min^{-1} thawing rate had the lowest sperm motility recovery index. Mounib's sucrose-based diluent + hen's egg yolk had the highest motility recovery index at all thawing rates. Mean percent motility for fresh sperm (87.7 ± 2.9%) was not significantly different than of sperm cryopreserved using Mounib's sucrose-based diluent + hen's egg yolk, frozen at -2.5°C min^{-1}, and thawed at 5.0°C min^{-1} (77.1 ± 2.9%). For Mounib's sucrose-based diluent + hen's egg yolk velocity was significantly higher with sperm thawed at 7.5°C min^{-1} than sperm thawed at 2.5°C min^{-1}, while thawing rate had no effect for Hanks' Balanced Salt Solution + hen's egg yolk. Our findings have implications for cod mariculture and aiding in conservation efforts for a dominant marine fish species.

Jan. 2010 – Dec. 2010 • Funded by: Genome Canada, Genome Atlantic, Atlantic Canada Opportunities Agency, Natural Sciences and Engineering Research Council of Canada, the Marguerite and Murray Vaughan Graduate Fellowship.
A complete list of supporting partners can be found at www.codgene.ca/partners.php

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Seasonal variations in seminal plasma and sperm characteristics of wild-caught and cultivated Atlantic Cod

The objective of this study was to investigate changes, throughout the spawning season, in body size attributes and quantitative semen characteristics of wild-caught and cultivated Atlantic Cod *(Gadus morhua)*. Sperm velocity increased significantly throughout the spawning season of cod from both origins. At the beginning and end of the spawning season, mean (± SEM) curvilinear velocity (VCL) for wild-caught cod increased from 78.9 µm s^{-1} (± 6.5) to 128.2 µm s^{-1} (± 6.5), respectively. For cultivated fish, mean (± SEM) VCL increased from 26.6 µm s^{-1} (± 2.4) in January to 48.9 µm s^{-1} (± 3.1) in March. Spermatocrit did not undergo a significant seasonal change in wild-caught cod, but did increase for cultivated cod (24.6% ± 4.2 in January to 40.5% ± 4.4 in April; $P < 0.01$). Sperm head area, perimeter, length, and width declined significantly at the end of the spawning season of cod from both origins (all P values < 0.01). Seminal plasma osmolality and Na^+ ion concentration followed a dome-shaped function through the spawning season for both wild-caught and cultivated cod ($P < 0.05$). For cultivated cod, seminal plasma pH was significantly lower at the start of the spawning season ($P < 0.001$), while Ca^{2+} increased and then decreased ($P < 0.05$). Body size attributes, spermatocrit, and seminal plasma constituents had significant relationships with sperm activity variables. These relationships varied as a function of time post-activation, month, and fish origin.

Jan. 2007 – Dec. 2010 • Funded by: Genome Canada, Genome Atlantic, Atlantic Cod Genomics and Broodstock Development Program, DFO – Aquaculture Collaborative Research Development Program (ACRDP), Natural Sciences and Engineering Research Council of Canada (NSERC), Dr. John S. Little International Study Fellowship
Marguerite and Murray Vaughan Graduate Fellowship

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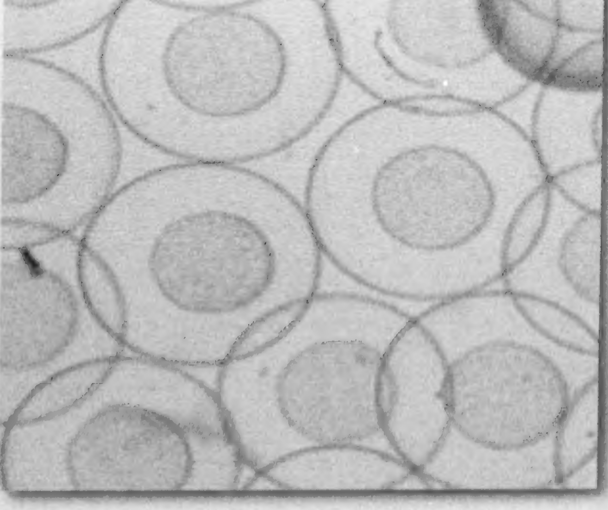
The effect of sperm to egg ratio and gamete contact time on fertilization success in Atlantic Cod

Currently, Atlantic Cod *(Gadus morhua)* is the primary finfish species being developed for aquaculture in North Atlantic waters. Despite the importance of this species, no research has been conducted to assess the effects of sperm density and gamete contact time on egg fertilization. In two separate experiments male and female gametes were crossed using nested factorial designs. For each male-female combination, we tested sperm to egg ratios ranging from 1×10^{4}:1 to 5×10^{6}:1. We also tested two-gamete contact times where sperm and eggs were held in contact with each other for 5 or 30 min. Mixed-model ANOVAs indicated that sperm density and gamete contact time had a significant effect on fertilization success. Below a sperm to egg ratio of 1×10^{5} to 1, fertilization success significantly decreased. Therefore, a standard sperm to egg ratio of 1×10^{5} sperm per egg is recommended for fertilization in Atlantic Cod. At the 1×10^{3}:1, 5×10^{3}:1, and 1×10^{4}:1 sperm to egg ratios, maximum fertilization occurred after 30 min sperm to egg contact time. Gamete contact time was not significant at sperm to egg ratios of 1×10^{5}:1, and 1×10^{6}:1. Both the maternal and paternal variance components were significant for fertilization success. This information has important implications for optimizing family production in selective breeding programs, conserving sperm from superior pedigree in genome banks, maximizing the use of available gametes in hatchery or research facilities, and understanding mating success in the wild.


Ian Butts (U of Windsor)

Atlantic Cod eggs at 26 hours post-fertilization

Jan. 2007 – Dec. 2009 • Funded by: Genome Canada, Genome Atlantic, Atlantic Cod Genomics and Broodstock Development Program, DFO – Aquaculture Collaborative Research and Development Program (ACRDP), New Brunswick Innovation Fund (NBIF), Natural Sciences and Engineering Research Council of Canada (NSERC)
Project team: Ian A.E. Butts (DFO – SABS, UNB now U of Windsor), M. Litvak (UNB), E. Trippel (DFO – SABS) • Contact: Ian Butts (iana.e.butts@gmail.com)

Optimized land-based tank farming of Atlantic Halibut in Canada

Over the next few years, Canaqua Seafoods Ltd. will improve production efficiencies of Atlantic Halibut aquaculture through the incorporation of innovative management tools and rearing facilities into their existing land-based grow out farm in Advocate Harbour, Nova Scotia. The initial phase of this project focused on enabling Canaqua Seafoods Ltd. to mechanically grade their halibut. This required infrastructure upgrades and installations. These were successfully completed, and the large halibut on the farm were graded. Populations were monitored for several months post-grading in order to assess the effect of size grading on performance. The set up for grading small halibut was also initiated. Grading had the clear and desired effect of reducing variation in the production tanks. Reduced population size variation increases feeding through the diminution of feeding hierarchies, and it improves fish stock management by improving accuracy of biomass and mean fish size estimations. It aids the determination of feed rations, the allocation of optimum feed size and the monitoring of fish performance and health. Soon after the fish were graded, growth rates seemed to increase with steady improvement through the winter months. There was a real reduction in time and effort required to grade the halibut when compared to the earlier manual grade techniques which likely would not even have been feasible at this stage of production.

Jul. 2009 – May 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), CanAqua Seafoods Ltd., Scotian Halibut Ltd.
Project team: Paul Merlin (CanAqua Seafoods Ltd.), John Bailey (CanAqua Seafoods Ltd.), Hugh Snow (Scotian Halibut Ltd.), Brian Blanchard (Scotian Halibut Ltd.), Melissa Rommens (Scotian Halibut Ltd.), Philip Nickerson (Scotian Halibut Ltd.), Forest Merlin (Merlin Fish Farms Ltd.), Roland Cusack, Scotian Halibut Ltd., NSDFA, NRC – Institute for Marine Biosciences
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Physical and biochemical properties of effluent leaving an onshore Atlantic Cod aquaculture facility and potential use in integrated multi-trophic aquaculture (IMTA)

Integrated multi-trophic aquaculture (IMTA) uses mussels to reduce waste and provide additional product. The physical and biochemical properties of Atlantic Cod *(Gadus morhua)* wastes were analyzed and the waste remediation potential of Blue Mussels *(Mytilus edulis)* was assessed. Waste generated daily by Atlantic Cod represented 24.9% of the feed added to the system. Effluent was composed of particles <70 µm (36%), 70-500 µm (31%) and particles >500 µm (33%). Particles <70 µm had significantly less organic matter, lipids and fatty acids and were expected to be ingested more by mussels than larger particles. The major lipid classes present in effluent were free fatty acids, triacylglycerols, phospholipids, acetone mobile polar lipids and sterol. Effluent contained two essential fatty acids, DHA and EPA, a diatom marker (16:1ω7), as well as two zooplankton markers (22:1ω11 and 20:1ω9) which accumulated in mussels and may serve as markers for aquaculture wastes. Although only 36% of the effluent was a size suitable for mussel ingestion this size fraction has the greatest potential to spread to surrounding areas. The fatty acid profile of effluent suggests performance of mussels may be impaired if reared on effluent alone; however, effluent may be used as an alternate food source when natural seston is low.

Feb. 2008 – Feb. 2010 • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), Fisheries and Oceans Canada (DFO)
Project team: Chris Parrish (MUN), Adrianus Both (MUN), Randy Penney (DFO), Ray Thompson (MUN)
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IMTA site in the Bay of Fundy T. Chopin (UNBSJ)

Kelp harvest at IMTA site in the Bay of Fundy T. Chopin (UNBSJ)

CIMTAN: Canada's new network for Integrated Multi-trophic Aquaculture

The IMTA concept

Fulfilling aquaculture's growth potential requires responsible technologies and practices. Sustainable aquaculture should be ecologically efficient, environmentally benign, product-diversified, profitable and beneficial to society. Integrated Multi-Trophic Aquaculture (IMTA) has the potential to achieve these objectives by cultivating species from different trophic levels and complementary ecosystem functions, in proximity. These are cultivated in a manner that allows one species' uneaten feed and wastes, nutrients, and by-products to be captured and converted into fertilizer, feed, and energy for the other crops. This method also takes advantage of synergistic interactions between species while biomitigation takes place (partial removal of nutrients and CO_2, and supplying of oxygen). Farmers combine fed aquaculture (e.g., finfish or shrimps fed sustainable commercial diets) with extractive aquaculture, which utilizes the inorganic (e.g., seaweeds or other aquatic vegetation) and organic (e.g., suspension- and deposit-feeders) excess nutrients from fed aquaculture for their growth. In this way, all the cultivation components have an economic value, as well as a key role in the services and recycling processes of the engineered ecosystem. The aim is to ecologically engineer balanced systems for environmental sustainability (biomitigative services for improving ecosystem health), economic stability (improved output, lower costs, product diversification, risk reduction, and job creation for local communities), and societal acceptability (better management practices, improved regulatory governance, and appreciation of differentiated and safe products). In this way, some of the environmental interactions of fed monoculture are internalized, thus increasing the overall sustainability, profitability, and resilience of aquaculture farms. The economic values of the environmental and societal services of extractive species will have to be recognized and accounted for in the evaluation of the true value of these IMTA components. This will create economic incentives to encourage aquaculturists to further develop and implement IMTA. Seaweeds and invertebrates produced in IMTA systems should be considered as candidates for nutrient/carbon trading credits within the broader context of ecosystem goods and services. Long-term planning/zoning promoting biomitigative solutions, such as IMTA, should become an integral part of coastal regulatory and management frameworks.

The need for and development of CIMTAN

Research and development (R&D) on IMTA has been conducted on both the East and West Coasts of Canada since 2001. Significant progress has been made over the last nine years, but a concerted and strategic approach was needed for: the need for better coordination; synchronized complementary R&D to fill the knowledge gaps and explore new ideas; information sharing and intellectual and conceptual exchanges; sharing expensive equipment through joint experiments appropriately planned between the two coasts for optimal data acquisition and result analyses; joint inter-disciplinary training of highly qualified personnel; and increased involvement of industrial partners. This will allow IMTA to move from an interesting academic and experimental concept into a valued economic and social reality at a commercial scale.

CIMTAN is focused on developing a key network of researchers, with complementary expertise, from across Canada to further develop IMTA approaches to strategically enhance economically sustainable production systems. The ultimate goal of CIMTAN is to develop aquaculture systems, which can be adopted by its industrial partners. These systems will be able to efficiently mitigate organic and inorganic enrichment of fed aquaculture operations by actively recapturing this material and turning it into the production of extractive crops of commercial value. This will transform associated environmental and socio-economic issues around

Emily Nelson and Lindsay Orr deploy a cage of sea cucumbers at SABS Emily Nelson (UNBSJ)

aquaculture operations into benefits and trusted quality seafood and novel seafood-base products, not only for its industrial partners, but also for coastal and rural communities and all Canadians. With a strong pan-Canadian academic, government, and industry partnership, CIMTAN will provide the inter-disciplinary R&D and highly qualified persons (HQP) training on the following linked areas of IMTA:

- ecological design, ecosystem interactions, and biomitigative efficiency;
- system innovation and engineering;
- economic viability and societal acceptance; and
- regulatory science.

CIMTAN will also go beyond addressing natural science and/or engineering questions, and will address socio-economic and regulatory governance components, required for the full development of the sector. Additionally, CIMTAN will create the conditions for increased economic opportunities in coastal and rural regions, including First Nations communities, providing sustainable, quality seafood to Canadians, concomitant with increased societal acceptance of the aquaculture sector and public policy development for improved government decision-making.

CIMTAN structure

CIMTAN is based on a networking approach among 26 scientists from 8 universities, 6 federal laboratories of Fisheries and Oceans Canada, and 1 provincial laboratory, spread over 6 provinces. The complementary expertise, combined infrastructures, and the common goal of the 26 scientists, is in phase with the priorities of the 3 industrial partners (Cooke Aquaculture Inc., Kyuquot SEAfoods Ltd. and Marine Harvest Canada Ltd.) and the environmental, developmental and social issues of concern to First Nations. This has allowed the network to be structured into 3 linked Domains reflecting the 4 areas identified above. CIMTAN is structurally organized into domains: Domain 1 is environmental; Domain 2 is engineering; and both Domains 1 and 2 are linked by the cross-cutting Domain 3 (economic and social), as biological, environmental, and biotechnological/engineering issues are always linked to economic aspects and social acceptability. Each domain is co-led by a scientist at an academic institution and a scientist at a Fisheries and Oceans Canada laboratory, in recognition of the significant role played by Fisheries and Oceans Canada in this network. Domain 1 is co-led by Drs. MacDonald and Robinson; Domain 2 is co-led by Drs. Cross and Pearce; and Domain 3 is co-led by Dr. Knowler and Mr. Noce.

The management structure of CIMTAN has been designed to provide and ensure effective research planning, research delivery, management, financial control and accountability, and interaction among all actively committed members and partners of this complex inter-disciplinary and multi-institutional network. The key decisional structures of CIMTAN, the Steering Committee and the Scientific Committee, have been designed to give a balanced representation of academics, industry, provincial and federal governments, and non-governmental organizations (in particular the Aboriginal Aquaculture Association). This was designed to ensure a cohesive and effective approach of CIMTAN to the development of responsible aquaculture practices, linked to the priorities of its partners.

CIMTAN's total budget amounts to CAD$9,577,000. The Natural Science and Engineering Research Council (NSERC) support to the level of CAD$5,000,000 (52.2%) was able to leverage an impressive level of cash and in-kind contributions: CAD$637,210 (6.7%) in cash contributions (Fisheries and Oceans Canada, University of New Brunswick, Cooke Aquaculture Inc., and Marine Harvest Canada Ltd.) and CAD$3,939,790 (41.1%) in in-kind contributions (Fisheries and Oceans Canada, University of New Brunswick, Cooke Aquaculture Inc., Kyuquot SEAfoods Ltd., and Marine Harvest Canada Ltd.).

Training of highly qualified persons is a very high priority of CIMTAN (CAD$2.156 million or 43.1% of the NSERC budget). All projects are involved in this very important task of training the scientists, policy influencers, decision makers, regulators, and industrialists of tomorrow. It is anticipated that the 26 scientists of the network will support and train 114 HQP over 5 years: 23 MSc, 2 MASc, 4 MRM, 4 MA, 5 PhD students, 2 postdoctoral fellows, and 6 technicians. A large number of undergraduate summer students (68) will also be hired. CIMTAN is promoting student co-supervision, mobility among the domains, reciprocal laboratory visits, and placement terms at the different partner organizations. This will ensure inter-disciplinary training and versatile multi-sectoral experience with the different prevailing environmental, economic, and societal conditions of the different domains, institutions, organizations, and regions.

The research articles in this section describe in more detail, each of the 14 projects of CIMTAN.

Jan. 2010 – Dec. 2014 • Funding: All CIMTAN projects are funded by Natural Sciences and Engineering Research Council (NSERC), Fisheries and Oceans Canada (DFO), University of New Brunswick, Cooke Aquaculture Inc., Marine Harvest Canada Ltd., and Kyuquot SEAfoods Ltd.
Project team: T. Chopin (University of New Brunswick Saint John, Department of Biology), B. MacDonald (UNBSJ), S. Robinson (DFO – SABS), S. Cross (U Vic), C. Pearce (DFO – PBS), D. Knowler (SFU), A. Noce (DFO – EAS)
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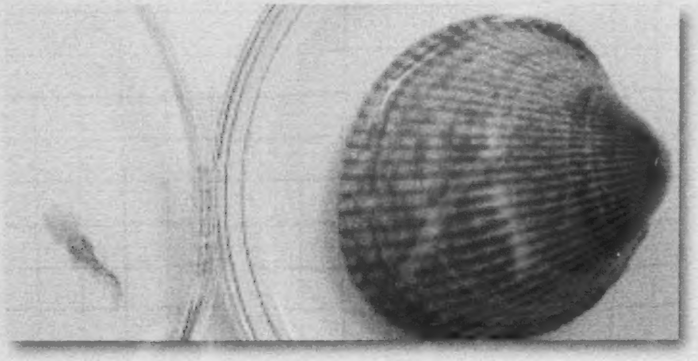
Mathematical modeling for open-water IMTA – Developing tools to support system design and measures of sustainability

Matter and energy flux within open-water IMTA systems and between the culture and the environment needs to be qualified and quantified in order to assess farm design and develop sustainability measures. Empirical measures of concentrations in open-water systems as a means to assigning causality to a particular process or culture niche has obvious challenges in such a highly variable and "leaky" environment. Some degree of modeling will therefore be essential to determine efficiencies and track the "delivery" of nutrients to co-cultured species. Since most commercial-scale aquaculture in Canada occurs in open-water systems, IMTA will also be practiced in this context. IMTA system modeling must therefore be developed beyond the laboratory and small-scale pilot projects if it is to have "real world" application. Therefore, the primary objectives of this project are to: reconcile existing ecological and animal/seaweed husbandry efficiency measures; continue the development of both a semi-stochastic nutrient-transfer model; determine the overall IMTA system efficiency of nutrient and energy recovery; and create a mechanistic/deterministic model with time steps to increase the understanding of IMTA systems. Together these will ultimately determine methods with which to quantify system functions for open-water IMTA farm management, economics, and coastal zone policy development. These objectives will be facilitated though the compilation of relevant data from the other CIMTAN projects.

Jan. 2010 – Dec. 2014

Project team: G. K. Reid (UNBSJ/DFO – SABS), B. MacDonald (UNBSJ), P. Cranford (DFO – BIO), M. Quinton (UGuelph), S. Robinson (DFO – SABS), T. Chopin (UNBSJ) • Contact: G. K. Reid (Gregor.Reid@dfo-mpo.gc.ca) • www.cimtan.ca



Janis Webb (UVic)

Gravid sea louse and adult Basket Cockle

Can filter-feeding bivalves ingest planktonic sea lice?

A possible benefit of adding filter-feeding shellfish to the typical monoculture model of salmon farming is the potential for reducing viral, bacterial, and/or parasitic diseases in the cultured fish as a result of the filtering of planktonic dispersal particles (e.g., bacteria, viruses, larvae, nauplii) by the shellfish. This project examines a number of filter-feeding shellfish species for their ability to ingest the planktonic nauplii/copepodids of sea lice under laboratory conditions and assessing the effects of commercial-scale quantities of shellfish on sea lice levels at a commercial salmon farm site. The laboratory phase of the project, currently underway, is designed to determine which of four species of suspension-feeding bivalves (i.e., blue mussel, Pacific Oyster, Basket Cockle, Japanese Scallop) consume sea lice larvae and the ingestion rates at various temperatures (5, 10, 15°C). If species are identified that can consume nauplii/copepodids, then a field experiment will be established to compare sea lice levels on cultured fish in: (1) experimental cages surrounded by commercial-scale densities of cultured shellfish, and (2) control cages and control sites without shellfish. If successful, bivalves grown by salmon farms could potentially reduce the abundance of sea lice on caged salmon using a biological control approach, possibly reducing the need for costly chemo-therapeutants.

Jan. 2010 – Dec. 2014

Project team: C. Pearce (DFO – PBS), S. Cross (UVic), S. Jones (DFO – PBS), S. Robinson (DFO – SABS), J. Webb (UVic graduate student)

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Perry Smith (DFO)

Gregor Reid hands an ADV current meter to Shawn Robinson and Andrew Cooper for deployment between mussel socks to collect data on current dynamics and nutrient delivery from salmon cages

Economic and financial modeling of IMTA

Assuming that IMTA can be shown to be an environmentally-favourable system of food production for society, IMTA adoption will depend on the profitability of the system and the necessary economic incentives to promote adoption. This project aims to: 1) examine the net economic benefits of IMTA and compare these to conventional aquaculture systems; 2) assess the private financial incentives for IMTA production at the site level; and 3) investigate appropriate financial incentives for the wider promotion of IMTA. This project will use both financial and economic analysis tools, where financial analysis examines the business's revenues and costs and economic analysis examines the net effects of an activity, including its effects to external parties. Studies to be carried out under this project will examine: 1) the impacts of commercial-scale IMTA on the BC shellfish industry; 2) consumer attitudes and willingness-to-pay for IMTA products in the Pacific Northwest; and 3) comparative economic analysis of nutrient dynamics in IMTA and conventional net pen salmon aquaculture. Additionally, other tentative studies are proposed to examine modeling of private incentives for adoption of IMTA among salmon farmers in BC and additional valuation studies.

Jan. 2010 – Dec. 2014

Project team: D. Knowler (SFU), P. Kitchen (SFU graduate student), W. Yip (SFU graduate student)

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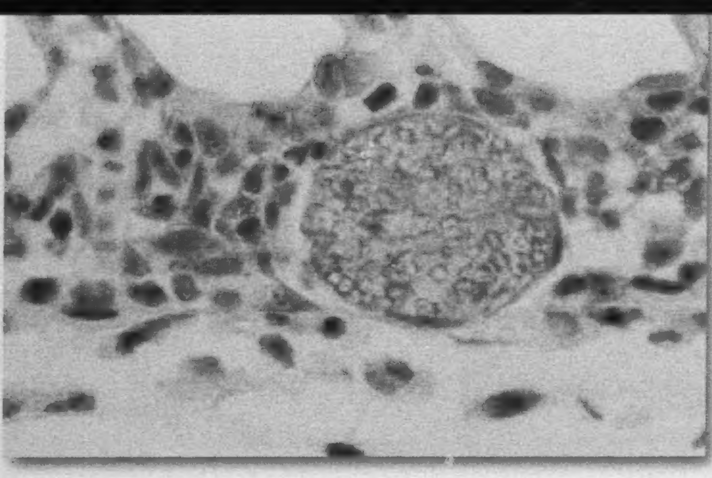

David Speare (UPEI)

Monoclonal antibody stained spores of *Loma salmonae* within a xenoma developing within the gill microvasculature

Temporal and spatial patterns of nutrient and organic particle plumes in IMTA systems

Delimitation of the spatial and temporal patterns and dynamics of the nutrient and particulate releases from different IMTA system configurations will provide critical information on the nature of the "leakiness" of these approaches. It will also inform on how the extractive species of these systems should be configured so as to maximize the ability to effectively intercept these waste streams. How these dispersion processes function within the natural fluctuations in nutrients, particulates and the inherent biotic assimilative capacity (e.g., phytoplankton) are also essential to understanding how IMTA systems should be designed and operated. Results from this project will help develop an appropriate balance of species components of the IMTA system, as well as assist with production infrastructure design and engineering for effectively incorporating these species components into a multi-species design. Two MSc students (one on each coast) are exploring direct and indirect methods for delimiting the spatial extent of these waste plumes, comparing existing profiling techniques with indirect productivity measures of seaweed sentinels (kelps). A third MSc student will examine the dispersion, benthic accumulation and the potential for nutrient release and/or particulate re-suspension from the settling particulate waste stream. A PhD student is developing new, optical (direct) techniques/protocols for delimiting the dissolved nutrient and particulate plumes emanating from the culture systems.

Jan. 2010 – Dec. 2014

Project team: S. Cross (UVic), M. Costa (UVic), F. Page (DFO – SABS), P. Cranford (DFO – BIO), J. Grant (Dalhousie University), G. Reid (UNBSJ/DFO – SABS), T. Chopin (UNBSJ), E. Prussin (UVic graduate student), L. Brager (Dalhousie University graduate student), S. Jabber (UVic graduate student)

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Steve Cross (UVic)

Lindsay Brager recording data at the Kyuquot SEAfoods Ltd. IMTA farm site

Use of blue mussels to reduce the horizontal transmission of *Loma salmonae*

As a general hypothesis, it is likely that the transmission of pathogens – and in particular the exchange of pathogens between the farm site and the "near-farm" environment – could be modified through IMTA practices. This may apply best, or alternatively may be most successfully modeled, for those organisms which possess methods of infection/transmission that allow extended periods of extracorporeal (off-host) survival and for which the severity of infection is quantifiable as a continuous outcome and directly (linearly) related to exposure to infectious dose. Given these considerations, the disease known as Microsporidial Gill Disease of Salmon (MGDS), a serious endemic gill disorder in marine netpen reared and wild Chinook (and other Pacific) Salmon, has potential as a model through which to better understand disease transmission in this modified aquaculture setting. Our goal is to develop a suitable laboratory *in vivo* branchial xenoma expression model for MGDS and use it to explore our specific aims which include determining to what extent blue mussels may remove, deactivate, or retain *Loma* spores released from infected fish. Additionally, we also seek a further understanding of the temporal kinetics of spore survival in marine environments and sediments, in addition to their survival (as determined through infectivity) within or on structures that may be used in IMTA settings.

Jan. 2010 – Dec. 2014

Project team: D. Speare (UPEI – AVC), J. Lovy (UPEI – AVC), N. Guselle (UPEI – AVC), E. Ball (UPEI – AVC), L. Collins (UPEI – AVC; Pfizer Health)

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Capture and conversion efficiencies of candidate organic extractive species

The potential of an organism as an organic extractive species within IMTA sites depends primarily on its efficiency to capture and convert particles. On the East coast, the potential of the Sea Cucumber *(Cucumaria frondosa)* as an organic extractive IMTA species is being determined by: 1) quantifying the absorption efficiency and its relationship to the quality of material present; 2) quantifying the time necessary to convert food to faeces (gut passage time); and 3) determining whether it is capable of consuming aquaculture waste. This project will use both controlled laboratory experiments and practical field trials in the natural environment and at East coast IMTA sites. Several species are being considered for use as organic-extractive organisms on the West coast. Ingestion rate, absorption efficiency, energy budget, and biophysical properties of excreted faeces will be determined for individuals fed diets of Sablefish aquaculture waste, and will be compared to "natural" diets across a range of temperatures. Candidate species for the West coast include the Green Sea Urchin *(Strongylocentrotus droebachiensis)*, the Basket Cockle *(Clinocardium nuttallii)*, the Blue Mussel *(Mytilus edulis)*, the Gallo Mussel *(M. galloprovincialis)*, the California Sea Cucumber *(Parastichopus californicus)*, the Pacific Prawn *(Pandalus platyceros)*, and nereid polychaetes.

Jan. 2010 – Dec. 2014

Project team: B. MacDonald (University of New Brunswick Saint John, Department of Biology), S. Cross (UVic), C. Pearce (DFO – PBS), S. Robinson (DFO – SABS), G. Reid (UNBSJ, DFO – SABS), H. Gurney-Smith (VIU – CSR), S. Balfry (UBC-DFO – CAER), E. Nelson (UNBSJ graduate student), L. Orr (UVic graduate student)

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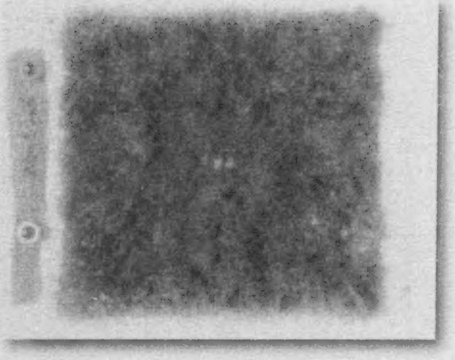

Isabelle Gendron-Lemieux (DFO – IML)

A collector plate retrieved at an IMTA site after 10 weeks. Colonised predominately with hydrozoans, it has accumulated 145 grams of biomass

Quantifying energy and nutrient dispersal and scales of influence on wild species from open-water IMTA sites

The abundance and distribution of wild species associated with IMTA cage sites need to be measured in order to learn how these species are associated with nutrient availability in both the near and far field. Current investigations will design an appropriate field methodology based on feasibility and statistical design. We have been able to quantify rates of bio-colonization (bio-fouling) using standardised collectors that are similar to designs used for monitoring invasive tunicates. Each collector consists of a series of PVC plates that serve as a substrate for native organisms such as bryozoans, hydrozoans, tunicates, and algae. These species colonise new substrates quickly and are suitable as measurements of early responses to nutrient availability. Collectors are deployed at both finfish and IMTA sites as well as at reference locations within the same geographic area but far from aquaculture activity. Upon collector retrieval, total accumulated biomass and surface area colonised can be measured and compared among sites relative to other environmental variables. The next phase of investigation will be to deploy a full array of collectors around several IMTA and finfish sites along with simultaneous measurement of environmental correlates such as temperature, salinity, current, chlorophyll, and oxygen.

Jan. 2010 – Dec. 2014
Project team: A. Cooper (DFO – SABS), S. Robinson (DFO – SABS), C. McKindsey (DFO – IML), F. Page (DFO – SABS), L. Burridge (DFO – SABS), T. Chopin (UNBSJ)
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Presence, effect, and bioaccumulation of therapeutants in polychaetes

The goal of Integrated Multi-Trophic Aquaculture (IMTA) systems is to recycle and reuse excess nutrients from salmon aquaculture farms by culturing other commercially valuable species, thereby limiting environmental impacts. Co-culture of the Clam Worm, *Nereis virens* - a sediment dweller commonly found in the Bay of Fundy - is being considered as a means to "process" the organic solids that settle out from fish farms. This worm is often sold as bait. The goal of this project is to determine the effects of the anti-sea lice therapeutant SLICE® (active ingredient emamectin benzoate (EB)) to these worms at fish farms where this chemical is used. Ongoing toxicity studies are assessing acute and chronic effects of this therapeutant on the worms. During an acute exposure study, worms were exposed to EB concentrations of 20, 200 and 2000 µg/Kg-sediment for 10 days. This resulted in no mortality although some behavioural changes were observed. A chronic exposure study will be conducted in which worms will be exposed to similar concentrations but over 60 days. Survival, uptake of EB, and growth will be monitored. This work provides data that will be used to assess the feasibility of culturing worms under salmon farms.

Jan. 2010 – Dec. 2014
Project team: L. Burridge (DFO – SABS), K. Kidd (UNBSJ), G. Reid (UNBSJ/DFO – SABS), S. Robinson (DFO – SABS), T. Chopin (UNBSJ), G. McBriarty (UNBSJ graduate student)
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Cultivation of complementary inorganic extractive species for increased system performance

Since 2001, the inorganic extractive component of IMTA systems on the East coast has been composed of the two kelps *Saccharina latissima* and *Alaria esculenta*. On the West coast, *Saccharina latissima* has been cultivated since 2007. These species are cultivated first in the laboratory, from September to November, and then at the sites from November to June/July. They need to be harvested in late spring/early summer before the erosion of the blades and fouling compromises the harvest and quality of the derived products. Consequently, inorganic biomitigation is not taking place during summer, as seaweeds are absent at IMTA sites. This project is investigating two new macro-algal candidate species, on the East coast *Palmaria palmata* (Dulse) and *Ulva* sp. (Sea Lettuce) on the West coast. These macrophytes have cycles and characteristics that allow growth of the macroscopic stages during the summer. This will allow the provision of biomitigative biomass during the summer and, consequently, an overall increase of the inorganic biomitigative capacity of the IMTA systems. Research is also underway to explore the use of seaweeds in fish feed formulation as alternate protein sources to partially offset fishmeal and land plant proteins.

Thierry Chopin (UNBSJ)

Two new candidates for the inorganic extractive component of IMTA: the Red Alga, *Palmaria palmata* (Dulse), and the Green Alga, *Ulva* sp. (Sea Lettuce), among the species already cultivated, the Brown Alga *Saccharina latissima* and *Alaria esculenta* (kelps)

Jan. 2010 – Dec. 2014
Project team: T. Chopin (University of New Brunswick Saint John, Department of Biology), S. Cross (UVic), C. Chiarnale (UNBSJ graduate student), N. Sherrington (UVic graduate student)
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The design of new infrastructure components for increased operational efficiencies

Aquaculture sites can be located remotely far from the electrical grid. As the intent is to reduce environmental impact of aquaculture operations, the provision of clean power on aquaculture sites is being investigated to avoid the need for diesel gensets (fossil-fuel powered generators). The work to date has been focused on gathering resource data for the West coast IMTA demonstration site, and performing initial component sizing. The use of on-site bioreactors to process seaweeds to produce biodiesel was explored but found to be unfeasible due to inefficiencies of scale. There was insufficient seaweed input available from target site operations with which to create the required quantity of biodiesel for energy self-sufficiency. An alternative approach involved employing wind and solar energy sources to power aquaculture operations. Wind and insolation data were gathered from existing weather collection buoys and it was found that significant solar power was available to be used as an alternate power source. To ascertain the wind resource characteristics at the height of candidate turbine installations, a higher anemometer tower is currently being installed. An energy system model has been assembled in HOMER that includes the hoist power requirements, the source of the primary power load (i.e., power consumption). HOMER is a simulation code that is used for analysis of remote energy systems. It simulates the power flows in those systems between, for example, batteries, motors, wind turbines, etc. and produces an output of performance, costs, etc. An energy efficiency audit has also been conducted of the on-site aquaculture staff residence. These data will be included in the custom energy usage model that is being developed to optimize the aquaculture power usage system. A custom model was developed as it was found that existing software was unable to adequately accommodate for the intermittent "peaky" power loads, a function of hoist use. The custom power model could then be used to size renewable energy systems for current and future aquaculture sites.

Jan. 2010 – Dec. 2014
Project team: C. Crawford (UVic, Department of Mechanical Engineering), S. Cross (UVic), T. Chopin (UNBSJ), E. Hoevenaars (UVic graduate student)
Contact: C. Crawford (curranc@uvic.ca)

Caitlin Piper (UVic)

Mary Liston, the first CIMTAN graduate student to successfully defend her M.A. thesis on November 19, 2010

Social implications of IMTA

Canadian coastal communities are small, widely dispersed, and have a high degree of economic and cultural diversity. In recent years, many of these communities have experienced economic hardships, the result of downturns in the capture fishery and forestry sectors. One of the goals of this project is to investigate the potential that IMTA has for contributing to the development of sustainable coastal livelihoods in remote communities. This objective requires considerations of the capacity and interest of people in participating in aquaculture and of the policies and training needed to facilitate their involvement. Developing a better understanding of the social and institutional aspects of implementing IMTA in coastal communities directly complements the natural science aspects, and is an essential component in the overall process of helping IMTA reach its full potential. Recognizing that the health of social, economic, and ecological systems are inextricably linked, our research program has been developed with an explicit acknowledgement of the need to move across traditional academic disciplines and managerial "silos". Accordingly, this project is divided into three cross-cutting inquiry streams: a) aquaculture governance; b) the potential contribution of IMTA to Canada's coastal economy and social sustainability; and c) First Nations and IMTA.

Jan. 2010 – Dec. 2014
Project team: T. Chopin (UNBSJ), M. Flaherty (University of Victoria, Department of Geography), G. Murray (VIU), M. Liston (UVic graduate student), A. Belanger (UVic graduate student), J. Foley (UVic graduate student)
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The role of microbes in recycling nutrients of organic material

Understanding the various paths and processes by which energy flows through an IMTA site is one of the main objectives in the creation of sustainable aquaculture systems using ecosystem-based approaches. As food from one trophic level is recycled through another, the energy associated with organic particles is stripped out and is converted to inorganic waste products, such as ammonia or carbon dioxide or heat. This transfer occurs right down to the lowest trophic levels where the bacteria reside. The objective of this project is to evaluate the role that bacteria play in nutrient recycling at a salmon aquaculture site and to evaluate the relative scale of their ability to convert organic particles into inorganic components. Specifically, we will be enumerating bacteria and their respiration rates on and away from finfish aquaculture sites in both the water column as well as the benthos. This will be done on a seasonal basis at IMTA sites on both the East and West coasts. Additionally, we will also identify the bacterial communities associated with the aquaculture sites and how they evolve over the year. These results will be fitted into a model of energy flow through an IMTA site.

Jan. 2010 – Dec. 2014
Project team: S. Robinson (DFO – SABS), B. Forward (NBRPC), T. Lander (DFO – SABS), T. Chopin (UNBSJ), K. Mitchell (UNBSJ summer student)
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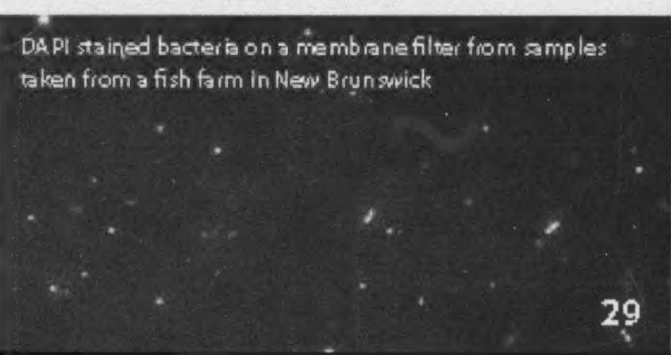
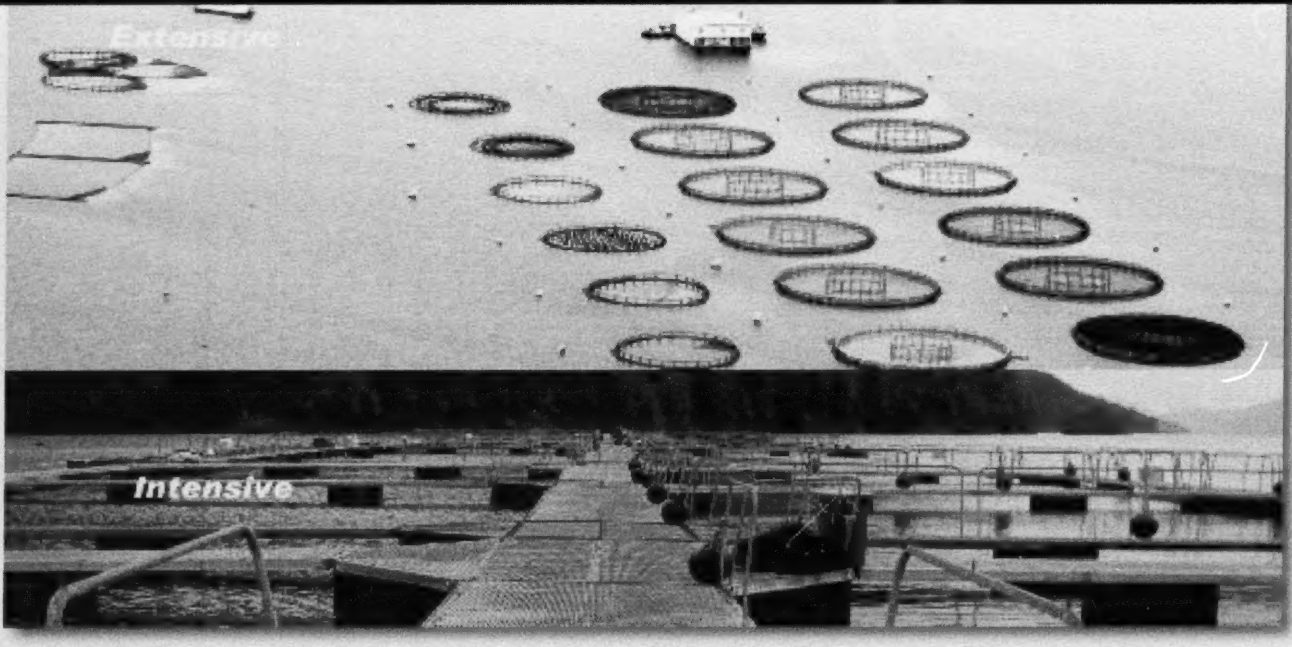

DAPI stained bacteria on a membrane filter from samples taken from a fish farm in New Brunswick

Kelli Mitchell (UNBSJ)



Shawn Robinson (SABS)

Intensive (British Columbia) and extensive (New Brunswick) IMTA farm sites. These systems will be compared as to their relative efficiencies in nutrient recapture

Optimizing component stocking densities and infrastructure for maximizing system efficiency

In light of the differing regional IMTA developments in Canada, it is clear that the design and engineering challenges manifested in adapting existing finfish aquaculture systems to support IMTA integration are considerable and varied. Hydrographic processes will dictate how dissolved nutrient and particulate plumes flow among these differing major infrastructure components. These characteristics will define how the IMTA production systems should be designed and configured to fully capitalize on the dispersion pathways of these waste streams. However, the interception of these streams by the various extractive species can, in themselves (at commercial production levels), affect the efficiency of the resulting IMTA system. Proximity to the fed (fish) component, density of the grow-out structures (nets, cages, trays), vertical and horizontal orientation with respect to the flows, within-production unit densities, and spatial/temporal integration of multi-species/multi-year classes within each type of IMTA system are all issues that need to be addressed in order to ensure continual and optimal system performance. This work will start in years 4-5 of CIMTAN with two MSc students and will compare the effects of system configuration on extractive performance of "intensive" IMTA systems on the West coast and "extensive" IMTA systems on the East coast.

Jan. 2010 – Dec. 2014
Project team: S. Robinson (DFO – SABS), S. Cross (UVic), C. Pearce (DFO – PBS), T. Chopin (UNBSJ)
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Extensive versus intensive IMTA systems

Research and development on IMTA has been conducted in Canada since 2001. During this period IMTA was developed independently on each coast, with integrated aquaculture systems being proposed through modifications of existing infrastructure currently employed for the culture of salmon within these regions – on the East coast using the independent circular cage grid configuration, and on the West coast integrated with the consolidated steel cage systems. Documentation of the dispersion and dilution pathways for these components, specifically the near-field hydrographic flow properties, is being determined for each of these IMTA production systems in order to provide the most efficient ecological and structural design. This component of the CIMTAN research program supports a comprehensive evaluation of flow impedance by structures, the effects of waste stream deflection (i.e., developed back-eddies, re-direction of flows), the vertical entrainment of particles (for the potential persistence of nutrients), effects of increased biomass on dissolved oxygen dynamics, alteration of phytoplankton supply through the systems, and structural adaptation of IMTA to capitalize on the effect of flow on dissolved nutrient and particle movements. One M.Sc. student is completing a comparative study documenting the near-field hydrographic properties of intensive and extensive IMTA farms, while a second will focus on the influences of infrastructure on near-field flows and its implications for within-system design/engineering of IMTA components.

Jan. 2010 – Dec. 2014
Project team: S. Cross (UVic), F. Page (DFO – SABS), M. Foreman (DFO – IOS), G. Reid (UNBSJ/DFO – SABS)
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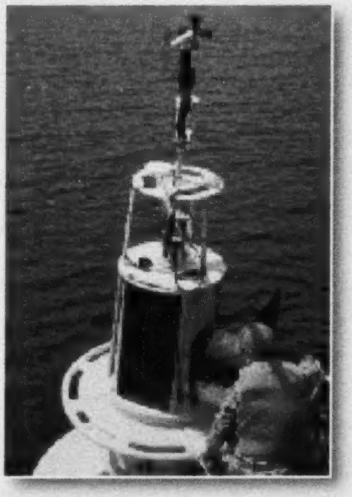
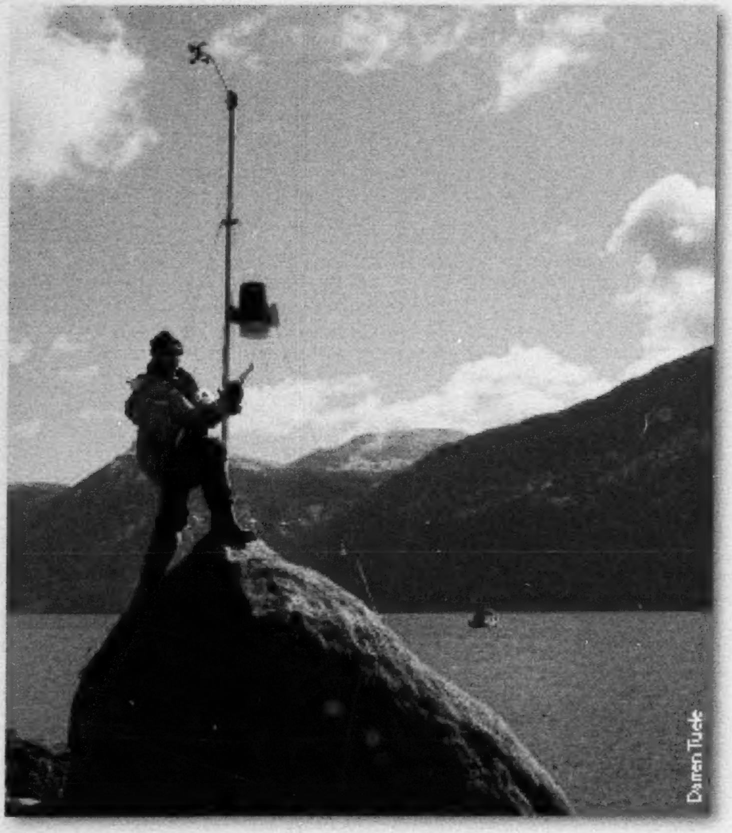


Steve Cross (UVic)

The multi-parameter University of Victoria CARMS buoy positioned upstream of the Kyuquot SEAfoods Ltd. IMTA farm site


Darren Tuele

Weather station maintenance at Surgeon Island

Bioassay protocol development to determine susceptibility of sea lice from BC salmon farms to therapeutants

This BC Centre for Aquatic Health Sciences (BC CAHS) project concerned with the transfer of bioassay procedures from the AVC Centre for Aquatic Health Sciences in PEI and international research facilities to BC CAHS. These methods were further adapted to the field and laboratory conditions and to the sea lice species found in British Columbia. Initial development of the bioassay protocol was supported by Intervet Schering-Plough and Marine Harvest Canada. Since April 2010, nine bioassays have been conducted. All assays tested for susceptibility to SLICE® (emamectin benzoate), which is the only sea lice therapeutant currently available in BC. All bioassays showed good susceptibility of sea lice to SLICE® – this finding corroborates efficacy studies of BC sea lice treatments with this therapeutant.

Mar. 2010 – Oct. 2010 • Funded by: Intervet Schering-Plough, Marine Harvest Canada
Project team: Alexandra Eaves, Sonja Saksida (BC CAHS), Intervet Schering-Plough, Marine Harvest Canada, Marine Harvest, Atlantic Veterinary College's Centre for Aquatic Health Sciences
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Spatial distribution of planktonic sea lice in the Broughton Archipelago

Development of effective farm location and management practices requires ongoing knowledge of where the sea lice larvae are located, how far and fast they spread from farm sources of adult sea lice and eggs, and how long the larvae remain present and infective after outputs from the farm sources are reduced by treatment or harvest. In support of this goal, this project accessed the distribution of planktonic larval sea lice in Knight Inlet and the Broughton Archipelago. Sampling was conducted in mid-late autumn (Nov-Dec; after the return migration of adult wild fish, but before mid-winter fallowing and pesticide treatments), when we anticipated that sea lice larval numbers may be higher in order to give us a more accurate picture of larval sea lice drift. However, larval sea lice abundances remained relatively low in the 2009 samples. This may be due to SLICE® applications and harvesting at farm sites 1-2 months earlier than in the previous year. Past works concentrated on getting into the field before the smolt out-migration. These previous studies showed that although spring-season abundances of the sea lice larvae were quite low in 2007 and 2008 (and at detection limit in 2009), local spatial maxima of the sea lice larvae were consistently located near active fish farms. The spatial association was strongest for the nauplius but was also significant and persistent for the copepodite infective stage. The fall distribution of planktonic stages is similar to spring; *Lepeophtheirus salmonis* more closely associated with farms sites and *Caligus clemensi* further afield. The project provided validation data for the Stucchi and Foreman computer model of sea lice dispersal and advection. Sampling was undertaken where the model showed "hot spots" of accumulation by wind and currents on the outer reaches of the Broughton Archipelago. In this region, the numbers of sea lice larvae were not large but were located in areas as defined by the model.

Jan. 2009 – Dec. 2009 • Funded by: DFO – Program for Aquaculture Regulatory Research, DFO Science
Project team: Moira Galbraith (DFO), Dave Mackas (DFO)
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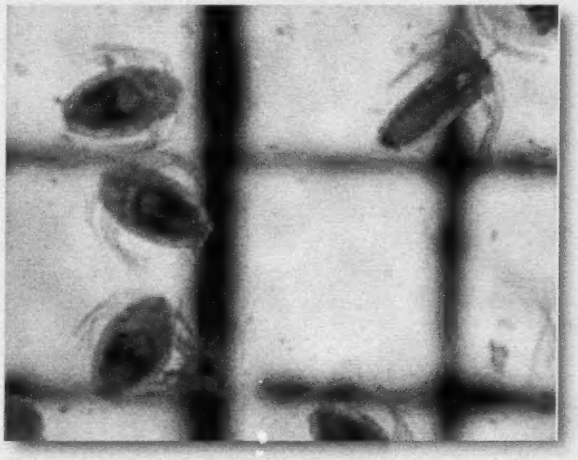
Formalin preserved newly hatched sea lice (*Lepeophtheirus salmonis*) at nauplii stages I and II, as viewed though a microscope. Background reference grid is 1 mm


Moira Galbraith (DFO)

Modeling sea lice dispersion and encounter rates with juvenile Pacific Salmon

Sea lice dispersion modeling initiated by the Pacific Salmon Forum and the Program for Aquaculture Regulatory Research (DFO) is continuing in collaboration with the new Broughton Archipelago Management Plan (BAMP) project whose objective is to explore means for reducing the potential for sea lice from farmed salmon to infect juvenile Pink and Chum Salmon during the outward migration season. Sea lice copepodid concentrations will be computed by coupled circulation and dispersion models for the Broughton Archipelago and used to estimate encounter rates with juveniles migrating seaward along pre-specified routes. The model grids have been improved to provide increased resolution around farms and coastlines, and various coastal boundary approximations will be tested to determine their effects on sea lice retention. A hindcast simulation for May 2008 will be compared with a similar run for March 2008 in order to estimate the impact of freshwater on sea lice mortality. A May 2010 run will also be compared with May 2008 to assess inter-annual variability. Methodologies to compare these concentrations and encounter rates with values arising from BAMP's wild salmon monitoring program will also be investigated. In the second year of the project, model coverage will be extended to the Discovery Islands area utilizing the circulation component of a viral transmission model that is presently under development with funding from Aquaculture Collaborative Research and Development Program.

June 2010 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research, Marine Harvest Canada

Project team: Mike Foreman (DFO), Dario Stucchi (DFO), Darren Tuele (DFO), Moira Galbraith (DFO), Peter Chandler (DFO), Crawford Revie (UPEI), Sharon DeDimonicis, Craig Orr, Ming Guo • Contact: Mike Foreman (Mike.Foreman@dfo-mpo.gc.ca) • www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/types-eng.asp

Environmental fate of SLICE® (emamectin benzoate) in saltwater aquaculture

Sea lice infestation at marine cage finfish farms in Canada are most often treated by the application of the anti-parasitic chemotherapeutant SLICE®. Concerns regarding the potential effect and uptake of the active compound in this treatment, emamectin benzoate (EB), by non-target organisms have been raised by numerous stakeholder groups. The goals of this project are to measure EB environmental levels, conduct laboratory exposure experiments at environmentally relevant concentrations where water, sediment and tissue concentrations can be measured, and to use genomic techniques to assess toxicological impacts on Spot Prawns.

As part of the field study, the benthic fate and concentration of EB and its desmethyl metabolite were evaluated following the application of SLICE® at finfish farm sites in BC. Ultra-trace analytical methodologies based on liquid chromatography electrospray ionization mass spectrometry were developed at DFO – IOS to measure EB in sediments, water and tissue matrices at low to sub parts per billion (ppb) levels. Preliminary data of the EB concentrations measured in the sediments near a salmon farm treated with SLICE® are presented in the figure below. The EB levels measured at the reference site were close to the limit of quantitation and were consistently low throughout the entire sampling period. At this site, the EB concentrations were highest underneath the net-pen (i.e., W0 and E0) with the highest concentration reaching 30 ppb some three weeks after SLICE® treatment commenced. These findings suggest that EB emerging from this salmon farm after SLICE® treatment were sequestered in the sediments in close proximity to the fish farm, i.e., within a 60 to 100 meter radius from the farm site. Residues of EB seem to dissipate over time and with distance from the net-pens. These EB profiles are specific to this site and may not be extrapolated to other sites. It is evident from our on-going work that the EB profiles in the sediments are site dependent and are closely related to the deposition characteristics of the specific location. Sites with low deposition characteristics had very low levels of EB (sub-ppb) in the sediments underneath the net-pen following SLICE® treatment.

Sediment, water, and Spot Prawn samples were collected from several sites treated with SLICE® and have been analyzed for EB. Presently we are analyzing these data for relationships between environmental concentrations and toxicological findings. The measured environmental EB concentrations are also being used to test, calibrate and implement the DEPOMOD model to predict the behaviour of EB in relevant aquatic ecosystems. These findings will be useful in developing policy for SLICE® utilization.

Nov. 2008 – Mar. 2012 • Funded by: DFO – Program for Aquaculture Regulatory Research, BC Ministry of the Envioronment, Pacific Salmon Forum, Pacific Prawn Fishers Association (PPFA))
Project team: Michael Ikonomou (DFO – IOS), John Chamberlain (BC Ministry of Agriculture and Lands), Eric McGreer (BC Ministry of Environment), Cory Dubetz (DFO – IOS), Chris Sporer (Pacific Prawn Fishers Association (PPFA))
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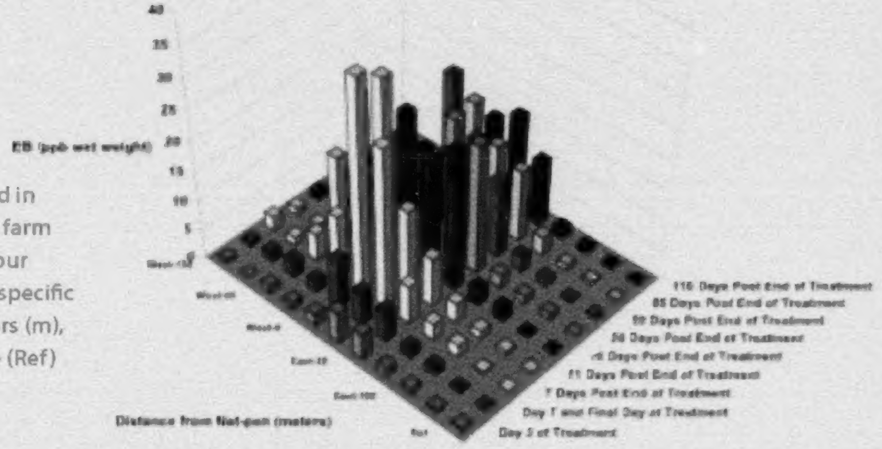

EB concentrations (ppb wet weight) as measured in surface sediment samples collected at a salmon farm site along East (E) and West (W) transects over four months of sampling. Samples were collected at specific distances East and West from the farm at 0 meters (m), 30 m, 60 m, 100 m and 150 m as well a reference (Ref) site. Average moisture level for all samples was determined to be 69.7% ± 11.4%

Michael Ikonomou (DFO)

Can sea lice carry and transmit bacterial and viral pathogens to salmon?

The role of ectoparasitic sea lice in disease propagation (as a possible vector) or in progression (impacts on the host's immunology) has not been explored. There are two phases of research underway in our lab: 1) experimental testing of the potential of sea lice as a pathogen vector – through acquisition and transfer of *Aeromonas salmonicida* and infectious haematopoietic necrosis virus (IHNv) between salmon hosts; and 2) the genetic examination of changes in the salmon immune response to sea lice feeding to test the hypothesis that sea lice feeding activities promote small, localised patches of reduced immune response, potentially acting as portals of pathogen entry. For objective 1, we have evidence that sea lice can acquire *A. salmonicida* and IHNv passively from waterborne exposure; however, the concentrations must be very high (similar to a disease outbreak). We also have evidence that sea lice can acquire these pathogens from feeding on infected salmon (Atlantic, Pink, or Chum). Our current experiments are examining the hypothesis that infected sea lice can transmit these pathogens to uninfected salmon, thereby completing the cycle of host › vector › host. For objective 2, data suggest that there are distinct differences among Atlantic, Pink, and Chum Salmon in genomic expression of various immune-associated genes. Pink Salmon have been found to have significantly elevated levels of interleukin-1, Beta (IL1β) (inflammatory responses). In addition, there are differences in the amount of gene expression from 24-48 hours post exposure to sea lice, with Atlantic Salmon often showing the highest initial expression. These studies continue with the addition of new variables including responses at the cellular level, the presence of bacteria, and duration of expression. As we progress through our second year of this project, the role of sea lice as a vector remains unclear. Thus, much of our current focus is on replication of transmission challenges through the examination of several key variables:

- vector potential between male and female sea lice;
- host susceptibility to "contaminated" sea lice (i.e., sea lice from infected Atlantic Salmon transferred to uninfected Pacific salmon and *vice-versa*);
- behaviour/viability of sea lice in varying environmental conditions (i.e., temperature, salinity) when carrying bacteria; and
- immunohistochemical detection methods of the pathogens on/in the sea lice.

Duane Barker (VIU)

Bacterial culture plate

2009 – 2012 • Funded by: NSERC Strategic Grant
Project team: Duane Barker (Vancouver Island University), Simon Jones (DFO), Kyle Garver (DFO), Diane Morrison (Marine Harvest), Brad Boyce (Marine Harvest), Stewart Johnson (DFO – PBS), Sonja Saksida (BC Centre for Aquatic Health Sciences), Luis Afonso (BC Centre for Aquatic Health Sciences), Ben Koop (University of Victoria), Scott McKinley (University of BC), Eva Jakob (VIU), Laura Braden (VIU), Colin Novak (VIU), Danielle Lewis (VIU)
Contact: Duane Barker (duane.barker@viu.ca)

Development of genomics tools to assess potential biological effects of SLICE® on Spot Prawns

SLICE® (emamectin benzoate (EB)) is used in medicated feed to control against juvenile motile pre-adult and adult stages of sea lice species on farmed salmon. EB enters the aquatic environment in uneaten feed and via fish feces. Concerns regarding the potential effects and uptake of EB by non-target organisms have been raised by numerous stakeholder groups. Genomic methodologies were developed to assess the risk of sub-lethal effects of EB on Pacific Spot Prawn, Pandalus platyceros, under laboratory conditions. Spot Prawns were exposed to selected concentrations (100, 400, 800, 1200 and 4800 ppb) of EB for up to 8 days. EB was spiked into the sediments placed in the aquariums where the spot prawn where placed.

It is well-established that RNA production varies with many environmental conditions and that differential gene expression does not necessarily indicate changes in protein production or cellular functions. The results from this study indicated changes in differential gene expression within muscle tissue from Spot Prawns exposed to the selected EB concentrations under these laboratory conditions. Accordingly, work is now proceeding to determine if the alterations are functionally relevant or meaningful. Additional cloning and QPCR initiatives have been undertaken that include a cDNA subtraction technique. This PCR-driven methodology will focus the design of QPCR tools for further screening of EB-exposed Spot Prawn. In addition to the laboratory exposed animals, we will also examine animals collected in the field close to fish farms following SLICE® treatment.

Apr. 2009 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR), BC-MOE, Environment Canada (EC), PSF, University of Victoria
Project team: Michael Ikonomou (DFO), Caren Helbing (University of Victoria), Nik Veldhoen (University of Victoria), Cory Dubetz (DFO), Jon Chamberlain (Ministry of Agriculture and Lands), Graham van Aggelen (EC), Craig Buday (EC)
Contact: Michael.Ikonomou@dfo-mpo.gc.ca
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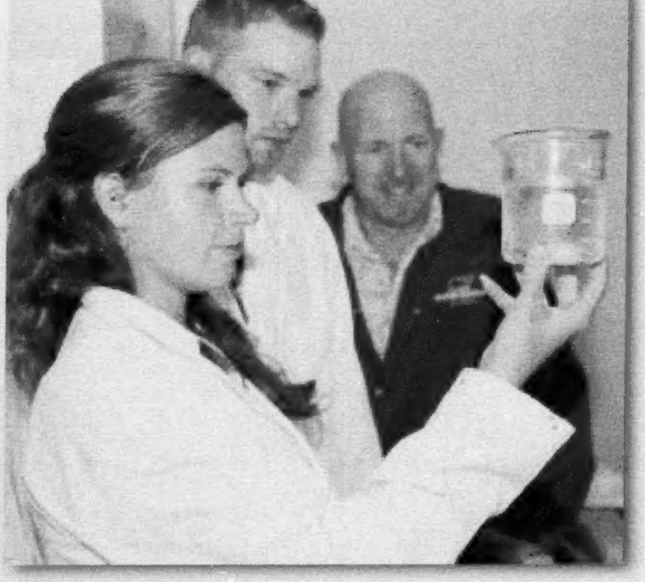


Duane Barker (VIU)

Barker Lab team

Genomics in Lice and Salmon (GiLS): using genomics to combat sea lice infections in salmon

Sea lice infections of salmon populations can threaten this important economic and environmental resource in British Columbia. Costs to the Canadian salmon industry to treat sea lice infections, keep farm stock healthy, and minimize environmental impact have been estimated at 10 to 20 percent of the total landed value, or more than $50 million in 2010.

The Genome BC-funded team of researchers (University of Victoria's Ben Koop, Simon Fraser University's William Davidson, Fisheries & Oceans Canada's Simon Jones, and Vancouver Island University's Grant Murray) is using microarray technology to examine gene expression patterns of both salmon and sea louse to identify which genes undergo significant changes in expression during infection. Identification of genetic markers in sea lice will enable the examination of population characteristics, including migration patterns, origins and selection, which will in turn provide information about the genetic factors that influence the host-pathogen response.

The team is identifying common genetic elements required for infection that could provide potential targets against which therapeutics can be developed to affect both species of sea louse. The analysis will provide important insight into the host-pathogen interaction, including the identification of resistant strains of salmon and more virulent strains of sea louse. This genomic strategy can also be employed to investigate the environmental variables that influence infection in order to potentially limit infection in farmed salmon populations.

Oct. 2008 – ongoing • Funded by: Genome British Columbia, BC Ministry of Agriculture and Lands, Fisheries and Oceans Canada (DFO), Grieg Seafood BC Ltd., Mainstream Canada, Marine Harvest, Microtek Research and Development Ltd., University of Victoria, Vancouver Island University
Project team: Ben Koop (U of Victoria), Grant Murray (VIU), Simon Jones (DFO – PBS), William Davidson (SFU)
Contact: Ben Koop (bkoop@uvic.ca) • http://web.uvic.ca/grasp/gils/

The biology of juvenile Pink Salmon and the impact of sea lice on the earliest stages of Pink Salmon in seawater

This study investigated the biology of juvenile Pink Salmon (*Oncorhynchus gorbuscha*) and the impacts of sea lice, (*Lepeophtheirus salmonis*), on the earliest stages of Pink Salmon in seawater. Controlled laboratory experiments were performed under natural conditions at a fallowed fish farm at Doctors Islet. Additional non-field based laboratory studies were performed at the Centre for Aquaculture and Environmental Research in West Vancouver and at UBC.

The research objectives were to perform sound laboratory and field studies to increase basic knowledge on the ionoregulatory physiology and performance of developing juvenile Pink Salmon and the effects of varying sea lice densities on these functions. The six research studies revealed that:

i) The relatively early entry of Pink Salmon into seawater (at about 0.3 g body mass) occurs prior to full physiological readiness for seawater life when compared to other anadromous salmonids. At this life stage, they have a strong preference for the top 1-2 meters of the water column.

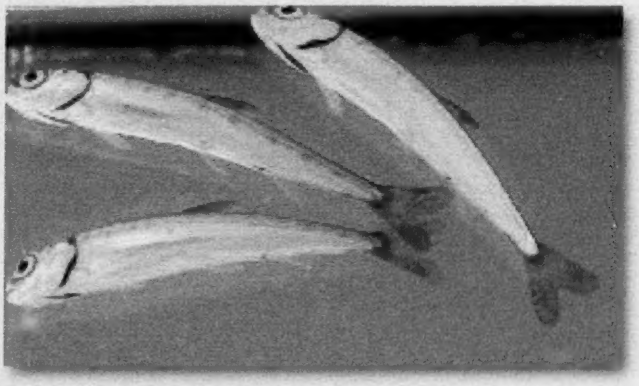
ii) The voracious appetite and high growth rate in seawater can result in a doubling of body mass each month. After about 1-2 months of such growth, seawater readiness appears complete.

iii) Juvenile Pink Salmon were discovered to be more resilient to controlled infections of sea lice copepodids than previously thought. Very little fish mortality was observed over a 1-month period of infection. Juveniles could lose sea lice (as previously reported in all controlled infection studies) and increased body mass even as the sea lice developed towards adult stages.

iv) The swimming performance and ionic balance of Pink Salmon was disrupted by sea lice infections only when the juveniles were less than 0.5-0.7 g in body mass.

v) The vertical and diurnal distribution of Pink Salmon was influenced by the presence of sea lice in a 10 m water column.

Feb. 2007 – Mar. 2011 • Funded by: British Columbia Pacific Salmon Forum, Natural Sciences and Engineering Research Council of Canada (NSERC)
Project team: A. P. Farrell (UBC), C. J. Brauner (UBC), L. Nendick (UBC), S. Tang (UBC), M. Sackville (UBC), A. M. Grant (UBC), M. Gardner (UBC), L. M. Hanson (UBC), A. G. Lewis (UBC), C. DiBacco (UBC) • Contact: A. P. Farrell (farrell@mail.ubc.ca)
http://people.landfood.ubc.ca/anthony.farrell/



Pink salmon juveniles Ted Sweeten (DFO – PBS)

Sea lice infection of juvenile Pink Salmon: effects on swimming performance and post-exercise ion balance

Sea lice *(Lepeophtheirus salmonis)* infection negatively affected swimming performance and post-swim body ion concentrations of juvenile Pink Salmon *(Oncorhynchus gorbuscha)* at a 0.34 g average body mass but not at 1.1 g. Maximum swimming velocity (U_{max}) was measured on over 350 individual Pink Salmon (0.2–3.0 g), two-thirds of which had a sea lice infection varying in intensity (one to three sea lice per fish) and life stage (chalimus 1 to preadult). For fish averaging 0.34 g (caught in a nearby river free of sea lice and transferred to seawater before being experimentally infected), the significant reduction in U_{max} was dependent on sea lice life stage, not intensity, and U_{max} decreased only after the chalimus 2 life stage. Experimental infections also significantly elevated post-swim whole body concentrations of sodium (by 23%–28%) and chloride (by 22%–32%), but was independent of sea lice developmental stage or infection intensity. For fish averaging 1.1 g (captured in seawater with existing sea lice), the presence of sea lice had no significant effect on either U_{max} or post-swim whole body ions. Thus, a single *L. salmonis* impacted swimming performance and post-swim whole body ions of only the smallest Pink Salmon and with a sea louse stage of chalimus 3 or greater.

Sept. 2009 – Apr. 2012 • Funded by: British Columbia Pacific Salmon Forum, Natural Sciences and Engineering Research Council of Canada (NSERC)
Project team: L. Nendick (UBC), M. Sackville (UBC), S. Tang (UBC), A. P. Farrell (UBC), C. J. Brauner (UBC) • Contact: L. Nendick (laura.nendick@gmail.com)
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Pink Salmon osmoregulatory development plays a key role in sea louse tolerance

Sea lice *(Lepeophtheirus salmonis)* of fish farm origin have been implicated in reducing Pink Salmon *(Oncorhynchus gorbuscha)* populations in British Columbia's Broughton Archipelago. Due to the physically disruptive nature of sea louse attachment to fish skin in a hyperosmotic environment, we hypothesize that impacts on fish performance are ionoregulatory in origin. Ionoregulatory status was measured in juvenile Pink Salmon artificially infected in the laboratory and naturally infected in the wild. Body [Na^+] of laboratory-infected fish (approximately 1 wk SW; 0.2-0.4 g) increased significantly by 12% with a single chalimus 4 sea louse, and by 23% with 2-3 chalimus 3 sea lice. Mortality over this 24-day trial was 2.4% for fish initially infected with 1-3 sea lice. Body [Na^+] for fish caught with natural infections (approximately 4-12 wks SW; 0.5-1.5 g) did not differ from uninfected controls. Combining data sets revealed body mass threshold of 0.5 g for fish infected with one chalimus 4 sea louse above which there was no effect on body ions. We propose that this size-related sea louse tolerance is associated with normal development of better hypo-osmoregulatory abilities, adding to a previously suggested multi-factorial mechanism based on epidermal and immune system development. We suggest management bodies consider this fish mass threshold when planning to minimize risk to wild fish populations.

Feb. 2007 – Mar. 2011 • Funded by: British Columbia Pacific Salmon Forum, Natural Sciences and Engineering Research Council of Canada (NSERC)
Project team: M. Sackville (UBC), S. Tang (UBC), L. Nendick (UBC), A. P. Farrell (UBC), C. J. Brauner (UBC) • Contact: M. Sackville (mikesack@zoology.ubc.ca)
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Modeling in support of Coordinated Area Management Production plan

As part of a British Columbia Pacific Salmon Forum (PSF) project, Dario Stucchi and Mike Foreman developed two computer models for the Broughton Archipelago: i) a three-dimensional numerical circulation model that, with appropriate forcing for specific time periods, is capable of simulating velocity, salinity and temperature fields throughout the region; and ii) a model of sea lice dispersal and development/behaviour that uses the 3D circulation model currents to disperse the planktonic larvae and model temperature and salinity fields to control their development and mortality. The Broughton aquaculture industry has recently proposed a Coordinated Area Management Production (CAMP) plan wherein a combination of SLICE® treatments and fallowing will be used to minimize potential sea lice infections on wild juvenile salmon migrating seaward past fish farms. As a guide to the future implementation of CAMP and in consultation with industry, we propose using our two models to investigate how the 2008 infective pressures would have changed under different treatment/fallowing scenarios.

Apr. 2009 – Mar. 2010 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR) • Project team: Dario Stucchi (DFO – IOS), Mike Foreman (DFO – IOS)
Contact: Dario Stucchi (Dario.Stucchi@dfo-mpo.gc.ca), Mike Foreman (Mike.Foreman@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp

Diel vertical distribution of early marine phase juvenile Pink Salmon and behaviour when exposed to sea lice

We observed diel vertical migration patterns in juvenile Pink Salmon *(Oncorhynchus gorbuscha)* and tested the hypothesis that fish behaviour is altered by exposure to sea lice copepodids. Experiments involved replicated field deployments of a large (9 m) plankton column, which provided a vertical distribution enclosure under natural light and salinity conditions. Diel vertical distributions of juvenile Pink Salmon were observed during the first three weeks of seawater acclimation both in the presence and absence of the ectoparasitic sea louse *(Lepeophtheirus salmonis)*. Immediately upon entering seawater, juvenile Pink Salmon preferred the top 1 m of the water column, but they moved significantly deeper down the vertical water column as seawater acclimation time increased. A significant diel migration pattern was observed, which involved a preference for the surface at night-time, compared with daytime. When fish in the column were exposed to *L. salmonis* copepodids for 3 h, 43-62% of fish became infected, fish expanded their vertical distribution.

Feb. 2007 – Mar. 2011 • Funded by: British Columbia Pacific Salmon Forum, Natural Sciences and Engineering Research Council of Canada (NSERC)
Project team: S. Tang (UBC), A. G. Lewis (UBC), M. Sackville (UBC), L. Nendick (UBC), C. DiBacco (UBC), A. P. Farrell (UBC), C. J. Brauner (UBC)
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Mixing in wellboats and cage treatment tarps and skirts

Chemical therapeutants are used as part of integrated pest management strategies by salmon growers in southwest New Brunswick to combat sea lice infestations. Efficient mixing of chemical therapeutants in treatment tarps and skirts and wellboat wells is desired for treatment efficacy. Studies took place in two well boats, the Ronja Carrier and Ronja, and at several farm sites, utilizing different chemical delivery systems. Fluorescent dye was injected into treatment vesicles with chemical therapeutants, following industry practices. Dye concentrations were measured at multiple locations and at multiple depths during the treatment period with fluorometers and the movement of dye was visually evaluated with time lapse photography. Results showed that mixing within wells was generally achieved approximately 10 minutes after the addition of the chemical and dye. The type of recirculation system in the wells impacts the rate of mixing. In tarps and skirts, the amount of time taken for the dye concentrations at the different locations to converge was far more variable and in general took longer than within the wellboat wells. It should be noted that mixing in wells was studied without the presence of fish, while mixing in tarps and skirts was monitored with fish present. Further work elucidating the importance of chemical dispersal method and behaviour of fish in mixing is planned.

NBSGA wellboat Ronja Carrier F. Page (DFO)

Jun. 2010 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR), DFO – Aquaculture Innovation and Market Access Program (AIMAP)
Project team: Fred Page (DFO – SABS), Randy Losier (DFO – SABS), Paul McCurdy (DFO – SABS), Jack Fife (DFO – SABS), Joelle Bakker (DFO – SABS), Blythe Chang (DFO – SABS), Mike Beattie (NBDAAF), Bruce Thorpe (NBDAAF), Kathy Brewer-Dalton (NBDAAF) • Contact: Fred Page (Fred.Page@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp

The ECO-Bath cage system: eco-friendly, safe and cost-effective ectoparasite control in finfish aquaculture operations

Sea lice have a global economic impact on salmonid aquaculture through loss of stock, product downgrades and costs involved in monitoring and managing infections. A sea lice epidemic recently occurred in New Brunswick as local sea lice populations become tolerant to a limited number of treatments. Present in-bath treatment methods are hampered by difficulties in obtaining and maintaining effective dose concentrations. Project partners are evaluating a new treatment system that will allow cost-effective field bathing treatments while minimizing total environmental impact from the sea lice treatment. Phase I was conducted in environmentally-controlled tanks. This experiment determined that there was no difference in pesticide toxicity between pre- and post-treatment fish when oxygen was infused to very high concentrations in the treatment bath water. Phase II is designing a commercial-scale ECO-Bath system to efficiently treat entire cages/sites while reducing total pesticide usage to a fraction of that presently required. Phase III field trials will evaluate the effectiveness of the ECO-Bath system to minimize total fish stress and mortality during commercial-scale treatments. The ECO-Bath system will increase productivity and operational efficiency through improvement of present fish health management tools and provide a green solution to sea lice control by dramatically minimizing pesticide discharge to the environment.

May 2010 – Mar. 2011 • Funded by: Aquaculture Innovation and Market Access Program, New Brunswick Innovation Foundation
Project team: Evan Kearney (Admiral Fish Farms), Amber Garber (Huntsman Marine Science Centre), Chris Bridger (Aquaculture Engineering Group), Phil Dobson (Aquaculture Engineering Group), Bill Hogans (Huntsman Marine Science Centre), Jack Pendleton (Admiral Fish Farms), James Snider (InVentures Technologies), Craig Glassford (InVentures Technologies), Mike Beattie (NB-DAAF), Kathy Brewer-Dalton (NB-DAAF), Clarence Blanchard (Future Nets) • Contact: Evan Kearney (e.kearney@admiralfishfarms.com), Amber Garber (agarber@huntsmanmarine.ca)

Effects of anti-sea lice pesticides on non-target organisms

"Sea lice" is a general name for ectoparasitic crustacean copepods that infest Atlantic Salmon. Severe infestations in aquaculture situations have led to loss of fish and revenue wherever salmon aquaculture has been practiced. In Canada, treatment with drugs and pesticides is required when infestations reach threshold levels defined by regulators and fish health professionals. Under current treatment practices, the drug or pesticide is released to the surrounding environment after the treatment, raising concerns about the potential risk to non-target organisms. Laboratory tests have shown that these dispersed therapeutants can be toxic to the American Lobster, which is often harvested close to aquaculture cage sites in Eastern Canada. Dr. Burridge's group has been investigating the nature of the pesticide AlphaMax® (active ingredient deltamethrin) lethal thresholds to the lobster and other crustaceans. Preliminary estimates of the 24-h lethality to lobsters range from 0.01 to 0.14 $\mu g\ L^{-1}$, depending on life-stage. Mysid shrimp are very sensitive to this product but sand shrimp are less sensitive than other species tested. These data, considered along with the results of dye dispersion studies conducted by Dr. Fred Page, will help assess the risk associated with the use of this product.

Lobster Larvae (DFO)

Apr. 2010 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
Project team: Les Burridge (DFO – SABS), Monica Lyons (DFO – SABS), David Wong (DFO – SABS), Ken MacKeigan (DFO – SABS), Susan Waddy (DFO – SABS), Vicky Merritt-Carr (DFO – SABS) • Contact: Les Burridge (Les.Burridge@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp

Potential for capture of chemical therapeutant active ingredients prior to release into environment

Chemical therapeutants are part of the integrated pest management strategies used by salmon growers for the control and management of sea lice. Current treatment technologies, wellboats and bath treatments, release the therapeutants into the surrounding environment once treatment is complete. While characterizing exposure and consequence of therapeutants is a time consuming and costly research effort, capturing the active ingredients prior to release would eliminate many of the questions concerning the use of chemical therapeutants in the aquatic environment and our reliance on effective risk management. For instance, preliminary trials using activated charcoal to filter Salmosan® (azamethiphos) and Alphamax® (deltamethrin) have shown > 90% efficacy in removing active ingredients. Planning for possible integration of charcoal filtration with emerging new cage treatment technology has begun. Exploration of methods for deactivating the therapeutants is also underway, given that filtration is challenging in wellboats due to the rates of water exchange.

Dec. 2010 – Mar. 2011 • Funded by: Department of Agriculture, Aquaculture and Fisheries of New Brunswick, Cooke Aquaculture Inc., Admiral Fish Farms, Northern Harvest Sea Farms, New Brunswick Total Development Fund
Project team: Mike Beattie (NBDAAF), Bruce Thorpe (NBDAAF), Kathy Brewer-Dalton (NBDAAF), Jiselle Bakker (DFO – SABS), Research and Productivity Council (RPC), Huntsman Marine Science Centre • Contact: Mike Beattie (Mike.beattie@gnb.ca)

Double and triple SLICE® dosage residue times in Atlantic Salmon

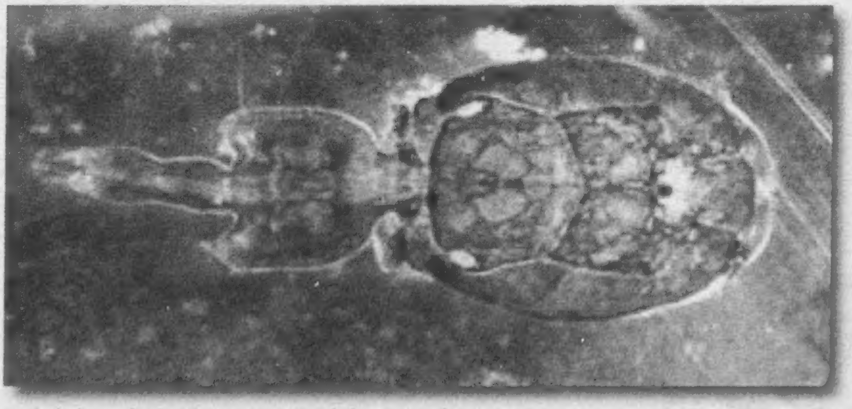
SLICE® (active ingredient emamectin benzoate) is an in-feed sea lice treatment for salmon in southwest New Brunswick and the only registered product to treat sea lice in Canada. Due to some instances of suspected tolerance and a continuing need for sea lice management, increased dosages are becoming more widely used. The purpose of this project is to establish the depletion curve for double and triple doses of emamectin benzoate (100 $\mu g \cdot kg^{-1}$ and 150 $\mu g \cdot kg^{-1}$ emamectin benzoate for 7 days, respectively) in salmon under controlled conditions and to validate the above using field-collected samples from a range of size classes and a variety of environmental conditions. This information is required to ensure that fish meet required withdrawal times and are under the maximum residue limits in order to maintain markets in Canada and the US. Work will be completed winter 2010-2011 and results disseminated to pertinent regulatory authorities, industry and other interested parties.

Dec. 2010 – Mar. 2011 • Funded by: Department of Agriculture, Aquaculture and Fisheries of New Brunswick, Schering Plough/Intervet Animal Health, New Brunswick Total Development Fund
Project team: Mike Beattie (NBDAAF), Rob Merritt (NBDAAF), Bruce Thorpe (NBDAAF), Kathy Brewer-Dalton (NBDAAF), Jiselle Bakker (DFO – SABS), Skretting, Cooke Aquaculture Inc.
Contact: Mike Beattie (Mike.beattie@gnb.ca)

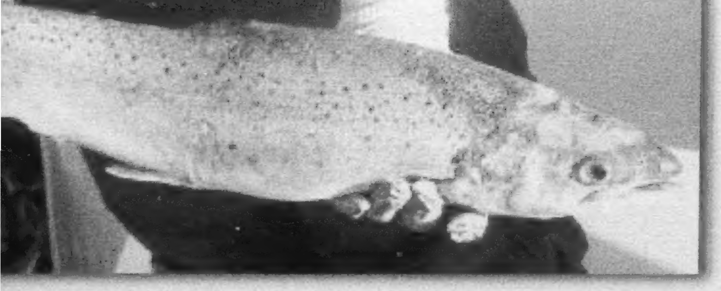
Evaluating transport and dispersal of chemical therapeutants: an oceanographic perspective

In the past couple of years, salmon growers in southwest New Brunswick have been using chemical therapeutants in bath and wellboat treatments to combat sea lice infestations. Once the salmon are exposed to the therapeutant for the prescribed time, the currently available treatment technologies release the chemical into the surrounding environment. Given that the chemicals are not specific to sea lice but target crustaceans in general, and that salmon farming is part of a complex multi-user environment, including local lobster and herring fisheries, characterizing the potential zone of influence of these treatments is integral for designing and applying appropriate management practices. Studies on the transport and dispersal of effluents from bath and wellboat treatments at multiple cage sites used fluorescent dye to track the effluent plumes. Fluorometry, visual plume perimeter estimations, time lapse imagery, and current profiles were used to observe the spatial extent of dye plumes and the temporal evolution of dye concentration within the plume. Water samples in the treatment cages and in the dye plume were collected and analyzed to develop dye-chemical relationships. Flushing of the dye from the treatment cages varied from minutes to hours and was likely influenced by net biofouling and current velocities. More data needs to be collected and existing data more fully analyzed to adequately describe the flushing plume characteristics from wellboats. The three dimensional distribution of the dye needs to be mapped to estimate the volume of exposure and be compared to local bathymetry to estimate the area of benthic exposure. Experiences to date indicate that individual site characteristics including depth, bathymetry and current velocities play an important role in effluent transport and dispersal, and hence exposure. Gathered information will be coupled with toxicological studies led by Les Burridge (DFO), Bill Ernst (EC), and Ken Doe (EC) to assist in assessing the risk associated with these treatments.

Jun. 2010 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR), DFO – Aquaculture Innovation and Market Access Program (AIMAP)
Project team: Fred Page (DFO – SABS), Randy Losier (DFO – SABS), Paul McCurdy (DFO – SABS), Jack Fife (DFO – SABS), Jiselle Bakker (DFO – SABS), Blythe Chang (DFO – SABS), Mike Beattie (NBDAAF), Bruce Thorpe (NBDAAF), Kathy Brewer-Dalton (NBDAAF)
Contact: Fred Page (Fred.Page@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp



Adult female sea louse *Lepeophtheirus salmonis* BC OAHS



Treated Atlantic Salmon M.Fast (UPEI)

Hydrogen peroxide bath effects on salmon skin epithelium

Hydrogen peroxide is used widely for the treatment of sea lice by the salmon industry at the current time. Field sea lice counts seem to indicate that fish treated with hydrogen peroxide suffer from a higher copepodid-chalimus re-infestation than fish treated with other bath chemicals. Our hypothesis is that hydrogen peroxide may affect the ultrastructure of the skin epithelium and subsequently the composition of the mucous layer, thus making it easier for sea lice reattachment. Damage to the dermis from this treatment may also release semiochemicals or chemo-attractants causing sea lice to be overly "attracted" to these fish. If results are positive, industry must then consider adjusting the timing of the hydrogen peroxide treatments in order to reduce the chance of re-infestation. This adjustment would also lead to fewer treatments throughout the year.

Jan. 2011 – Jan. 2012 • Funded by: Department of Agriculture, Aquaculture and Fisheries of New Brunswick, TDF, Novartis Animal Health Inc., AVC-UPEI
Project team: Mike Beattie (NBDAAF), Mark Fast (AVC-UPEI), Bruce Thorpe (NBDAAF), Kathy Brewer-Dalton (NBDAAF), Jiselle Bakker (DFO – SABS), Jennifer Covello (AVC-UPEI), Sara Purcell (AVC-UPEI), Novartis Animal Health Inc.
Contact: Mike Beattie (Mike.beattie@gnb.ca), Mark Fast (mfast@upei.ca)

Construction and evaluation of a scale model of a finfish cage under different flow regimes simulating bath therapeutant exposure

The salmon farming industry in eastern Canada is examining novel therapeutants for sea lice control, as part of a broader Integrated Pest Management Strategy. These products are delivered as either in feed treatments or as bath treatments in cages using tarps or fully enclosed in well boats. Two questions for bath treatment usage are how rapidly the therapeutants diluted/dispersed following treatment in the cages, and what are the implications for non-target organisms within tarps and well boats and how they are transported and dispersed following release from these containers. A scale model circular cage system was constructed and tested in the world's largest laminar flume tank under differing flow regimes simulating conditions across Atlantic Canada salmon farming locations. Systems were tested under tarped and untarped conditions to simulate therapeutant explore flow through tarped and untarped cage exposure in the field. The results showed rapid dilution/dispersion of bath therapeutants in the top layers of the water column representing various growout conditions in eastern Canada. The corollary is that therapeutants are not expected to reach non-target organisms on the sea bed under normal treatment operating conditions. These findings are useful for helping design and interpret field studies and data. The work will help provide input into regulator decisions as well as help improve knowledge of flow patterns through cages which in turn will help improve husbandry processes. The flume tank observations complement ongoing field trials, and collectively help facilitate rapid and cost effective assessment of potential treatment procedures prior to undertaking field assessments.

Jan. 2010 – Mar. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) Marine Institute of Memorial University (MUN)
Project team: Cyr Couturier (MUN), Fred Page (DFO – SABS), Gehan Mabrouk (DFO) • Contact: Cyr Couturier (cyr@mi.mun.ca) • www.mi.mun.ca/casd

Enhanced monitoring of sea lice using video technology

Regular and accurate sea lice counting is a vital part of sea lice control on salmon farms. However, the manual methods currently used are: time consuming; their accuracy is highly dependent on the skill of the human inspector; they require access to sea pens in increasingly exposed locations; and the crowding of fish to collect samples imposes additional stress on the fish. As a result, only a small number of fish can be sampled leading to problems with the statistical reliability of any population estimates. A passive, automated counting system offers the benefits of enhanced repeatability and accuracy, larger sample sizes, continuous monitoring, lower costs, and lower levels of disturbance for the fish. Such an approach, using underwater image capture and analysis techniques, was explored in a pilot study involving Scottish researchers in 2005-07. The success of this initial study has led to a follow-on innovation award under the Eurostars project *VisuaLice E!4721*.

The *VisuaLice* project builds on earlier work. It will trial pre-commercial equipment to validate this approach and calibrate the image capture and processing algorithms. These trials will take place in Scotland and Norway, with a research team that includes scientists and engineers from Iceland, England, and Canada. The Canadian involvement is mainly focused on the epidemiological interpretation of the data collected. The additional features and extensive nature of this data should better facilitate estimates of rates of population change, short term population variations, and enhance accuracy of prevalence estimation. The increased accuracy and temporal resolution provided by this novel approach will offer many benefits, including the ability to improve the timing and evaluation of treatment interventions, and achieve greater accuracy in the modeling of sea lice population dynamics.

Jeff Lines (Silsoe Livestock Systems)

Colour inverted image of adult sea louse attached to a salmon fluorescing under ultraviolet illumination

Jan. 2010 – Jun. 2012 • Funded by: ACOA AIF, Eurostars EU, RHF Norway
Project team: Jeff Lines (Silsoe Livestock Systems), Thorvaldur Petursson (Vaki Aquaculture Systems), Crawford Revie (UPEI), Gordon Ritchie (Marine Harvest ASA), Chris Wallace (Marine Harvest Scotland)
Contact: Crawford Revie (crevie@upei.ca)

Sea Lice Decision Support System (DSS)

The Sea Lice Decision Support System is a web-based application that allows users to enter, edit and review data and generate reports/graphs designed to assist those making treatment decisions associated with sea lice management on salmon farms. It is being developed by CAHS (AVC, UPEI) research scientists in collaboration with computer programmers. All data generated as part of both regular and targeted sea lice surveillance as well as all bioassay trial outputs are managed within the DSS. Once data are entered into the database, sea lice count summary reports and charts, as well as bioassay trial result graphs and reports are generated. Participating companies are able to access numerous summary charts associated with their sites as well as industry-wide averages.

Typical charts that are available by Bay Management Area (BMA) include: summaries of mean sea lice per fish, by sea lice stage; comparison of sea lice numbers with other sites over a given season or with respect to other production years, at various levels of aggregation; counting and treatment compliance reports to ensure coverage across the industry. Site-level charts are also available showing sea lice trends over time, by stage, allowing for an analysis of the efficacy of various treatment types. The ability is provided to drill down to detailed analysis of a treatment for a particular cage where pre and post-treatment sea lice levels by stage can then be used to assess the impact of any intervention over time.

In addition, all of the data and results from bioassays carried out on sites in New Brunswick are being stored in the DSS, with summary reports being available to farm management staff and prescribing veterinarians to aid in appropriate treatment selection. Because the DSS is web-based, the ability to assess bioassay result from sea lice treatments is also being offered to colleagues and researchers in other producing regions, which in turn could lead to AVC-CAHS becoming a global repository for this type of bioassay data.

Apr. 2010 – Mar. 2011 • Funded by: NB Dept. of Agriculture, Aquaculture and Fisheries (NBDAAF), ACOA-AIF, Atlantic Canada Fish Farmers Association (ACFFA)
Project team: Larry Hammell (UPEI), Crawford Revie (UPEI), Shona Whyte (UPEI), Jillian Westcott (UPEI), Holly Burnley (UPEI), Patti Jones (UPEI)
Contact: Larry Hammell (lhammell@upei.ca)

Sea lice treatment monitoring in the Bay of Fundy, NB

A team of researchers from the Atlantic Veterinary College's Centre for Aquatic Health Sciences (AVC-CAHS – UPEI) have been working closely with salmon farmers in Southern New Brunswick over the past year in a joint effort to monitor and combat the sea lice problems that have been hindering the salmon aquaculture industry. CAHS-driven activities include sea lice surveillance across the industry, training site staff in methods to conduct more accurate sea lice counts and the collection of sea lice from a range of sites to be used in laboratory bioassays. This comprehensive sea lice monitoring and management program is being funded through a collaboration among industry and governments.

CAHS technical staff conducted sea lice counts on many sites throughout 2010. While some routine weekly sea lice counts were conducted to monitor the effects of sea lice loads, most counts were carried out to monitor recently introduced sea lice treatments. Pre- and post-treatment sea lice counts were conducted on fish treated with SLICE®, Paramove®, AlphaMax®, Salmosan® and Ivermectin. Monitoring treatments in this way allows an assessment of the change in sea lice load on the salmon, which then helps determine the efficacy of the treatment. In addition to CAHS counts, sea lice counts done by farm staff are entered into an industry-wide decision support system for expanded sea lice and treatment response trend analysis.

These results are used to assist farms in making better treatment management decisions. Training on sea lice identification has been developed and offered by CAHS staff to industry multiple times, thus improving the ability to monitor sea lice at each developmental stage.

In addition to sea lice counts, our team has collected sea lice from numerous participating sites/companies for use in laboratory bioassays. Treatments that have been assessed in the lab include SLICE®, Salmosan® and AlphaMax®. A graduate student within the Centre is developing a bioassay for hydrogen peroxide (i.e., Paramove) treatments in 2011. All bioassays are standardized using vigorous sea lice, counted into multiple petri dishes, and exposed to varying doses of a treatment. Length of exposure depends on the type of treatment being used. After a 24-hour period, sea lice in every dish are observed and condition/vigour is recorded. Once analysis is complete, the efficacy of the treatment can be determined based on the number of sea lice that survive treatments at different doses.

Apr. 2010 – Mar. 2011 • Funded by: NB Dept. of Agriculture, Aquaculture and Fisheries (NBDAAF), ACOA-AIF, Atlantic Canada Fish Farmers Association (ACFFA)
Project team: Larry Hammell (UPEI), Crawford Revie (UPEI), Shona Whyte (UPEI), Jillian Westcott (UPEI), Holly Burnley (UPEI), Patti Jones (UPEI)
Contact: Larry Hammell (lhammell@upei.ca)

Better ways to apply bath treatments to control sea lice

A range of techniques exist with which to carry out bath treatments on salmon farms. These include the use of tarpaulins as "skirts" (draped around each cage) or, preferably, pulled under the cage to provide a complete enclosure, as well as the increased use of well boats. In addition, the advent of "super-size" cages able to hold at least a quarter of a million fish located in more exposed settings has led managers and scientists to question the nature of optimal treatment strategies for topical approaches. Of particular interest is the establishment of appropriate sampling methods to evaluate different types of topical intervention. This question is being explored as part of an international research project.

The *TopiLouse* project involves a number of Norwegian partners, including fish farming and pharmaceutical companies and well boat manufacturers, in addition to academic researchers from Norway, Scotland and Canada. The overall goal of this multi-disciplinary team is to improve the effectiveness of topical treatments used in sea lice control. A particular focus of the team at UPEI will be the examination of sampling and surveillance protocols associated with adequate sampling in modern fish farm environments. This will include a range of field sampling activities in both Norway and Canada involving intensive, farm-wide sea lice counting (e.g., sampling up to 100 fish from all cages on a site). These unique data sets will be analyzed using a simulation and mathematical modeling platform to provide guidance on how best to organize sea lice surveillance in the future.

Apr. 2010 – Sept. 2012 • Funded by: Research Council of Norway, ACOA AIF
Project team: George Gettinby (University of Strathclyde), Peter Andreas Heuch (Norwegian Veterinary Institute), Crawford Revie (UPEI) • Contact: Crawford Revie (crevie@upei.ca)

Automated oyster grading equipment for the BC shellfish processing industry

Keith Reid

Separately graded product ready for shipping

Currently, shellfish processors in Canada grade millions of oysters individually by hand. Given the volume of oyster production in BC alone, this system is inefficient and inconsistent. New mechanized grading technology has been developed overseas and promises significant benefits, including increased productivity, reduced labour cost, reduced labour effort, and a more consistently graded product.

This project involved the early adoption of mechanized grading technology that can lead to improved industry wide productivity, elevated grading standards and quality assurance for BC shellfish. Results using the new technology have exceeded the proponent's expectations. The automated grading equipment has increased production by nearly three times the amount possible with hand-grading, concurrent with a 65 percent decrease in production costs and steady overhead and labour costs. This translates into increased profitability, by an order of magnitude, and increased employee job satisfaction. The new 3D imaging technology has provided higher grading standards and increased consistency.

Markets demand consistency in product quality and the ability to make regular shipments; many markets will only accept product if there can be a promise of regular, high volume deliveries. This sustainability project sets a benchmark for oyster processing in Canada and positions the industry to respond to these market needs.

Mar. 2009 – Mar. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Odyssey Shellfish Ltd.
Project team: Keith Reid (President of Odyssey Shellfish Ltd.), Derek Diedricksen (Forbidden Alloy Products Ltd.), David McCallum (BC Shellfish Growers Association), S.E.D. Shellfish Equipment Pty Ltd. • Contact: Keith Reid (keith@stellarbay.ca) • www.stellarbay.ca

New clam harvesting technology

Clam digging technology in BC lags behind other parts of the world, where mechanical harvesters have been employed for decades. In BC, beaches are still dug manually with long-tined rakes. Clam growers struggle to attract workers to harvest clams because of the labour intensive nature of the work and uncertain wages.

To demonstrate the benefits of mechanical harvesting, the BC Shellfish Growers Association designed and built an adapted mechanical clam harvester. The Mark II harvester is now in use on BC clam growing beaches.

The Mark II harvests more clams, in less time, with fewer workers. The machine can harvest large beaches 2-3 times faster than manual harvesting, with one to two workers, compared to fifteen to sixteen workers with manual harvesting. Additionally, it harvests low density beach areas, and reduces losses from juvenile clam mortalities. An environmental impact study showed that the harvester's impact was no greater than manual harvesting.

As a result, mechanical clam harvesting technology is now available to clam growers in BC. This allows clam growers in the province to achieve significant productivity increases and provides a competitive advantage in the market place. The Mark II is an example of technical excellence aimed at sustainable resource use.

Apr. 2009 – Aug. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), BC Salmon Growers Association (BCSGA)
Project team: Roberta Stevenson (Executive Director BCSGA), David McCallum (BCSGA), Chris Baker (Taylor Shellfish Ltd.), Derek Deidricksen (Forbidden Alloy Products Ltd.)
Contact: Roberta Stevenson (roberta@bcsga.ca) • www.bcsga.ca

Basket Cockle: a new aquaculture species in BC?

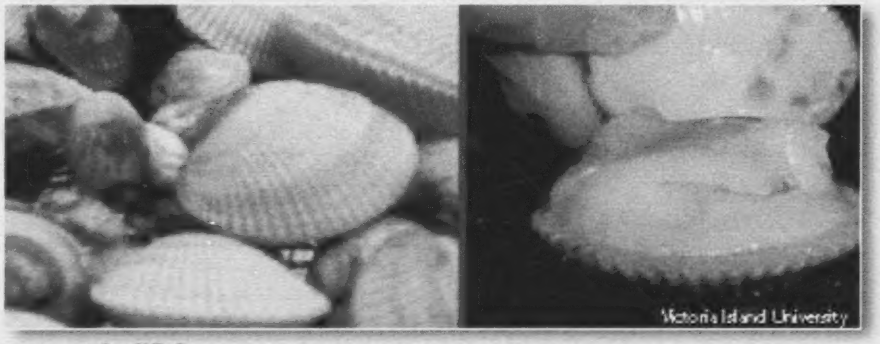
Could the indigenous Basket Cockle *(Clinocardium nuttallii)* become a new aquaculture species in British Columbia? To answer this question, a research project was recently completed with a grant from DFO–ACRDP, and co-funded by CSR and Evening Cove Oysters Ltd. Through a series of laboratory and field experiments, the feasibility of cockle aquaculture was assessed. An emphasis was placed on seed growth performance and qualities affecting final product marketability.

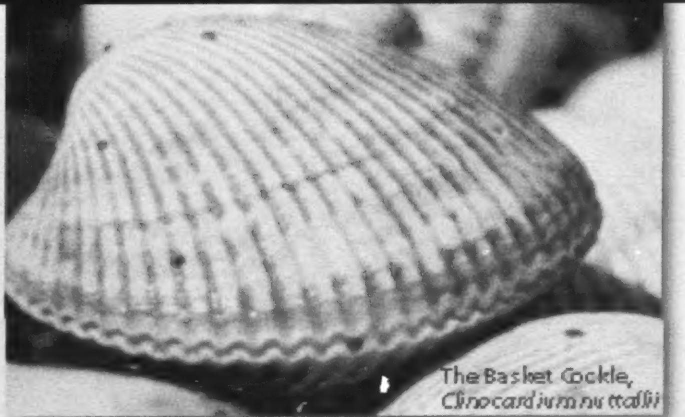
The effects of stocking density and substratum on seed survival and growth during the nursery phase were examined initially. The research then evaluated the combined effects of culture mode (intertidal and off-bottom suspended culture) and initial stocking density on cockle survival, growth, and condition during the first and second grow-out years. Finally, the effects of culture depth on cockle survival and growth in suspended culture were tested.

Depending on the grow-out mode, stocking density, and minimum harvestable size chosen, the cumulative harvestable proportion after the second year of grow-out constituted 15.5 to 63.1% of the initial seed planted. These values may be improved through further refinements of cockle grow-out techniques and/or tailored to the particular conditions of specific grow-out sites by the industry.

Aug. 2008 – Mar. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), CSR and Evening Cove Oysters Ltd.
Project team: Helen Gurney-Smith (CSR-VIU), Chris Pearce (DFO – PBS), Anya Epelbaum (CSR-VIU; presently DFO), Nadia Plamondon (CSR-VIU), Simon Yuan (CSR-VIU)
Contact: Helen Gurney-Smith (Helen.Gurney-Smith@viu.ca), Chris Pearce (Chris.Pearce@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

The Basket Cockle, *Clinocardium nuttallii*: (A) live; (B) shucked, grown in an off-bottom suspended system (note high soft-tissue biomass; meat yield ≥40%)


Victoria Island University



The Basket Cockle, *Clinocardium nuttallii*

Brian Kingzett (Vancouver Island University)

An assessment of the genetic and health status of the native Basket Cockle, in BC

The Basket Cockle, *Clinocardium nuttallii*, occurs on the Pacific coast of North America from San Diego to the Bering Sea. It occurs in sandy and muddy shores around the whole coast of British Columbia, and is therefore found in all five current shellfish transfer zones used by the regulatory bodies. Currently there is significant commercial interest in the Basket Cockle, due to their relatively rapid growth rate, ability to utilize different substrates, adaptation to the cold waters of British Columbia (BC), and their importance as a preferred First Nations food group. Previous research has supplied information on the broodstock, fertilization, hatchery, and initial on-growing stages. These earlier studies further emphasized the commercial aquaculture possibilities for this species.

The objective of this study is to comprehensively assess the genetic and health status of cockle populations throughout BC. Microsatellite markers will be designed and implemented, along with full health analysis for OIE-listed and regional diseases of concern. This information will be used to assist in the development of geographically species-specific management plans, which incorporate any potential genetic and disease transfer implications. This will aid in promoting cockle aquaculture in BC in a sustainable and ecologically responsible manner.

Nov. 2010 – Mar. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), We Wai Kai Nation, Aboriginal Aquaculture Association, Centre for Shellfish Research • Project team: Helen Gurney-Smith (Centre for Shellfish Research), Ruth Withler (DFO), Cathryn Abbott (DFO), Stewart Johnson (DFO), Shawn O'Connor (We Wai Kai Nation), Odd Grydeland (Aboriginal Aquaculture Association)
Contact: Helen Gurney-Smith (Helen.Gurney-Smith@viu.ca), Ruth Withler (Ruth.Withler@dfo-mpo.gc.ca) • www.viu.ca/csr/healthandhusbandry/Genetics.asp www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/projects/projects-eng.asp

Aquaculture husbandry practices and the genetic diversity of blue mussel populations

Selective breeding is commonplace in agricultural domestic plants and animals and has been used for hundreds to thousands of years to improve yields. This study examined how routine aquaculture practices and trait selection (quantitative and qualitative) may influence genetic diversity and what the implications are for future broodstock programs.

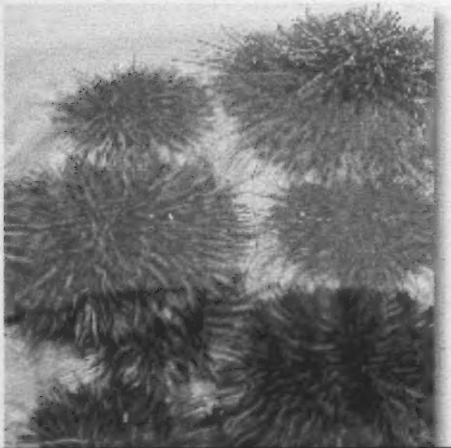
Multiple measures of genetic diversity were taken, including heterozygosity, from the Blue Mussel (*Mytilus edulis*) in three aquaculture populations in British Columbia (BC) and a wild population from its native range in Prince Edward Island.

Population analysis revealed that there were significant numbers of hybrids among the blue mussel and the other species in the BC aquaculture populations. The degree of hybridization and species complex observed was dependant on the aquaculture population tested. Genetic analysis determined that while there was a decrease in the genetic diversity between wild and aquaculture populations, there were also significant differences among the aquaculture populations. This may be related to broodstock development and husbandry processes, or might result from the randomness of genetic drift. Levels of heterozygosity (positively correlated to overall animal health and resilience) were similar in wild and aquaculture populations, which may be a transient condition after a genetic bottleneck occurs or a product of hatchery practices.

May 2009 – Mar. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Blue Frontier Investment Inc., Island Sea Farms Inc., Taylor Shellfish Canada, CSR
Project team: Helen Gurney-Smith (Centre for Shellfish Research), Cathryn Abbott (DFO) • Contact: Helen Gurney-Smith (Helen.Gurney-Smith@viu.ca), Cathryn Abbott (Cathryn.Abbott@dfo-mpo.gc.ca) • www.viu.ca/csr/healthandhusbandry/Genetics.asp www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/projects/projects-eng.asp

Pacific Golden Mussel™

Kenn Renaud (Blue Frontier Investment Inc)



Research uncovers potential for Purple Sea Urchin culture in BC

In the development of aquaculture of any new species one of the major obstacles to overcome is the production of healthy juveniles. Although information about the reproductive cycle and spawning of potential commercial species of sea urchins is readily available, information about larval culture and juvenile grow-out is still scarce, especially for the Purple Sea Urchin (*Strongylocentrotus purpuratus*). This research will concentrate on broodstock conditioning and larval rearing of the Purple Sea Urchin, a potential new candidate for aquaculture development in British Columbia. Specifically, research is focusing on the effects of various feeds (kelps and prepared diets) and temperature on gonad production and the effects of different natural feeds, feed rations, stocking densities, and temperatures on growth and the survival of larvae.

Sept. 2006 – Mar. 2011 • Funded by: Ontario Student Assistance Program, DFO
Project team: Chris Pearce (DFO-PBS), Scott McKinley (UBC), Kalam Azad (UBC)
Contact: Chris Pearce (Chris.Pearce@dfo-mpo.gc.ca)

Adult Purple Sea Urchins being held as broodstock Kalam Azad (UBC/DFO)

Chris Pearce (DFO)

Adult Pacific Geoduck Clams recently harvested from an intertidal culture plot in Washington state

Improving techniques for broodstock conditioning of Pacific Geoduck Clams

This research is aimed at finding which factors promote maximum fecundity in broodstock Pacific Geoduck Clams (*Panopea generosa*) reared in a hatchery setting. The effects of various temperature, salinity, and nutritional regimes on gonad development were investigated. The ranges of temperature and salinity were selected to reflect those typical of an estuarine environment in British Columbia (7 to 19°C and 17 to 29‰, respectively).

A temperature of 11°C was optimal with >90% of the clams maintaining ripe gonads with high numbers of oocytes and frequent spawns. Gonads remained ripe at 7°C, but spawning was inhibited. Temperatures above 15°C resulted in gonad degeneration. Salinities of 20‰ or lower were lethal to broodstock while gonad and gamete development were inhibited at a salinity of 24‰ compared to 29‰. The feed type (various combinations of *Isochrysis* sp., *Chaetoceros muelleri*, and *Dunaliella tertiolecta*) did not have significant impacts on gonad development, but overfeeding (>5 billion cells of *Isochrysis* sp. equivalent per day) had negative impacts on gamete production. The results of this study will be important in improving gamete production (and ultimately, larval production) in commercial-scale Pacific Geoduck Clam hatcheries.

Jan. 2008 – Mar. 2011 • Funded by: NSERC
Project team: Chris Pearce (DFO),
Scott McKinley (UBC), Rob Marshall (UBC)
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BC team studies nutritional requirements for sustainable crayfish aquaculture

Research is currently underway investigating the nutritional requirements and digestive physiology of juvenile Signal Crayfish (*Pacifastacus leniusculus*) in intensive aquaculture. Crustaceans make excellent candidates for aquaculture because they have high feed-conversion efficiencies and many are omnivorous and respond well to plant-based diets. The suitability of Signal Crayfish in aquaculture has been well established in Europe. Little is known, however, about their nutritional requirements for optimal growth, and there have been few attempts to culture them in their native range, which extends to southern British Columbia.

Understanding the nutritional requirements, energetics, and digestive capabilities of Signal Crayfish will provide a framework for assessing the suitability of locally-available, inexpensive, and ecologically-sustainable feed ingredients. The results of this study will provide valuable information for the development of crayfish aquaculture in Canada and serve as a basis for the development of other new species of crustaceans in aquaculture.

Crayfish aquaculture has the potential to provide economic stimulus with little or no detrimental effects or even a net positive effect on the environment. Accordingly, research is also underway to investigate the potential for Signal Crayfish to serve as a biological weed-control agent in eutrophic ponds such as those found on many golf courses.

Apr. 2010 – Mar. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Cordova Bay Golf Course
Project team: Chris Pearce (DFO), Dan Curtis (DFO), Zelko Djuric (Astacus Aquaculture Crayfish Consulting),
David Groves (Broken Briar Enterprises Ltd.), Dean Piller (Cordova Bay Golf Course)
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Assessing potential benthic impacts of intertidal and subtidal Geoduck Clam harvest

There has been widespread interest in the culture of the Pacific Geoduck Clam (*Panopea generosa*) in British Columbia (BC) for a number of years, but the commercial-scale development of this species has been hindered by a lack of governmental policy/legislation and concerns around how geoduck culture and harvest may impact the environment. These concerns are generally focused on the harvesting process, as high-volume water jets ("stingers") are used to liquefy the substratum around the clams in order to extract them. It should be noted that this technique is not just isolated to aquaculturists, as it is also the method used in the wild Geoduck Clam fishery. This research project aims to assess the effects of the Geoduck Clam harvest on the benthic sedimentary environment, nearby eelgrass beds, and the suspended sediment concentration. It will also examine how these effects vary spatially and temporally at both intertidal and subtidal study sites. The research results will address questions concerning the potential impacts of commercial-scale Geoduck Clam harvest on the benthic sedimentary environment and eelgrass populations and will help governmental agencies make informed decisions about the potential expansion of geoduck aquaculture (both intertidal and subtidal) in BC.

Sept. 2008 – Dec. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), BC Ministry of Agriculture, BC Ministry of Forests/BC Timber Sales, West Coast Geoduck Research Corp.
Project team: Chris Pearce (DFO), Wenshan Liu (DFO), Miriam O (DFO), Grant Dovey (West 7250 Resource Consulting Inc.), Bruce Clapp (West Coast Geoduck Research Corp.), Michelle James (West Coast Geoduck Research Corp.), Sean Williams (Abrupt Shellfish Inc.) • Contact: Chris Pearce (Chris.Pearce@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Harvesting cultured Pacific Geoduck Clams in the intertidal with a high-volume water jet called a "stinger"

Chris Pearce (DFO)

Cultured juvenile Pacific Geoduck Clams Chris Pearce (DFO)

Determining optimal microalgal diets and feeding rations for larvae and seed of the Pacific Geoduck Clam

The Pacific Geoduck Clam (*Panopea generosa*) industry in British Columbia (BC) has been constrained by the lack of a reliable seed supply, indicating possible inadequacies with the current hatchery production strategy.

The objective of this project is to evaluate the effects of various microalgal diets (single- and bi-algal) on the growth and survival of geoduck larvae and seed. The main goal is to identify optimal diets and the specific nutritional requirements (especially fatty acids) of larvae/seed and to ascertain vital nutrients imparting high nutritional value to the diets. The research will also identify optimal microalgal rations for both larvae and seed and examine the possibility of replacement of these live microalgae with commercially-available, spray-dried, microalgal diets.

The results of this project will contribute significantly to the establishment and refinement of hatchery-rearing protocols of geoduck larvae and seed, as well as to further expansion of the aquaculture industry of this species in BC.

Aug. 2010 – Sept. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Klahoose First Nation
Project team: Chris Pearce (DFO), Wenshan Liu (DFO), Scott McKinley (UBC), Ian Forster (DFO), Chris Roddan (Klahoose First Nation)
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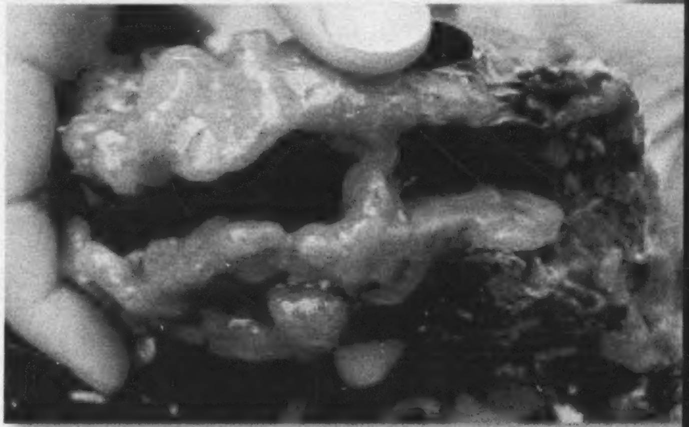
Assessing control methods for invasive tunicates in shellfish aquaculture

Currently, there are at least four species of tunicates in British Columbia which are non-native and potentially invasive: the Solitary Tunicate *Styela clava* (Club Tunicate) and the colonial tunicates *Botrylloides violaceus* (Violet Tunicate), *Botryllus schlosseri* (Golden Star Tunicate), and *Didemnum vexillum*. Recent monitoring surveys have detected some of these tunicate species at a variety of shellfish culture leases around British Columbia. This project is assessing the efficacy of various mechanical (scrubbing), biological (sea urchin grazing), and chemical (lime, acetic acid, brine, fresh water) means of tunicate control in Pacific Oyster aquaculture. Additionally, various concentrations and dip times of the chemical treatments are being evaluated for both their effects on the invasive tunicates and the shellfish themselves. Results will be of importance to shellfish aquaculture ventures as the industry requires effective, safe, and economical means of tunicate control.

May 2009 – Dec. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), DFO – Aquatic Invasive Species (AIS), BC Shellfish Growers Association
Project team: Tom Therriault (DFO), Chris Pearce (DFO), Soleil Switzer (DFO), Kate Rolheiser (VIU), Anya Epelbaum (DFO), BC Shellfish Growers Association
Contact: Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca), Chris Pearce (Chris.Pearce@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Invasive tunicate *Didemnum vexillum* on an oyster shell



Anya Epelbaum (DFO)

Developing genomics resources and tools for the health assessment of marine mussels (the Myt-OME projects)

The British Columbia coastline is under increasing pressure from competing coastal zone utilization (e.g., urbanization, recreation and aquaculture) and climate change impacts. The value of shellfish as a group to use to monitor ecosystem health and function is well recognized. However, their full potential has not been realized due to a lack of tools that can be applied to their assessment.

Within this program we are developing genomic information and tools for studying marine mussels (*Mytilus* spp.). In addition to being important in Canadian shellfish aquaculture, mussels are also widely used bio-indicator species of ecosystem health. cDNA subtracted and highly normalized libraries have been developed from mussels exposed to a variety of stressing agents. Bi-directional sequencing of these libraries has produced expressed sequence tags (ESTs), and currently genes are being selected for inclusion on a custom oligoarray. This array will be used in gene expression analysis, to examine the nature and magnitude of the stress response to environmental stressing agents. Over the long-term, these resources will be important for researchers and aquaculture managers interested in developing and improving mussel culture, as well as those utilizing mussels for assessments of coastal environmental health.

Jan. 2009 – May 2011 • Funded by: Genome British Columbia, DFO – Aquaculture Collaborative Research and Development Program (ACRDP), DFO – Program for Aquaculture Regulatory Research (PARR), Centre for Shellfish Research, Taylor Shellfish Canada
Project team: Helen Gurney-Smith (Centre for Shellfish Research), Stewart Johnson (DFO), Catherine Thomson (Centre for Shellfish Research, DFO), Daniel Sanderson, Gary Meyer, Kimberly Taylor, Genome British Columbia, Ben Koop (University of Victoria), Antonio Figueras (Consejo Superior de Investigaciones Científicas, Spain), Craig Newton (ATG Genetics), Taylor Shellfish Canada • Contact: Helen Gurney-Smith (Helen.Gurney-Smith@viu.ca), Stewart Johnson (Stewart.Johnson@dfo-mpo.gc.ca)
www.mytome.ca, www.viu.ca/csr/HealthandHusbandryGenomics.asp

Genomic tools for the assessment of impacts of aquaculture activities on Little Neck Clams *(Protothaca staminea)*

Often referred to as keystone species, bivalves are major components of coastal and estuarine ecosystems and play a prominent role in the development of ecosystem health indices and values, which can then be applied to ecosystems in general. It is well documented that stressful environmental conditions (natural or man-made) affect aquatic animal physiological performance (e.g., growth and fecundity), health and survival. Unlike finfish, for which sensitive biochemical assays, genomic tools and visual indicators of stress are available, there are few informative and reliable tools for bivalves. Through this project we developed genomic tools to aid in the study of native Little Neck Clam responses to environmental and anthropogenic factors. These tools will facilitate the use of this species as bio-indicators in the assessment of ecosystem health and resilience in the presence of aquaculture and other potential stressors. In 2008/09 we received funding to construct a cDNA library for Little Neck Clams. The 2009/10 project conducted expressed sequence tag (EST) sequencing with the goal of identifying genes that would serve as bio-indicators for stress and/or exposure to the aquaculture therapeutant SLICE®.

Apr. 2009 – Mar. 2010 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR) • Project team: Stewart Johnson (DFO – PBS)
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www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp

Technical and economic optimization of cooked mussel meat production procedures

The production of cooked mussel meat presents an attractive opportunity to reduce losses associated with the management of fresh mussel production. Cooking mussels preserves their initial quality and, once shelled, the meat can be frozen or brined and sold for various uses. The objective of the project was to optimize production procedures for cooked mussel meat and final products with a steam pressure cooker, an adaptation of a Dutch technology. The effect of the operating parameters was tested on the shelling rate, yield, and quality of cooked meat and final products for three categories of mussels. On the basis of the results obtained, standards were developed for small mussels and for the largest mussels. Throughout the testing, the shelling rate exceeded the recommendations (>90%). Additional tests will be required to obtain optimal results. This cooking technique looks very promising for the processing and marketing of blue mussels in Canada.

Aug. 2009 – Sept. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Société de développement de l'industrie maricole (SODIM), Centre technologique des produits aquatiques (CTPA)
Project team: Sylvain Lafrance (SODIM), Robert Vaillancourt (SODIM), Julie Pariseau (SODIM), Marion Voegtlin (Halieutec), Karine Berger (Halieutec), Marie-Joëlle Leblanc (Halieutec), Hervé Audet (Halieutec), Luc Leclerc (CTPA), Noëlla Coulombe (CTPA), Françoise Tétreault (Menu Mer Inc.)
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Integrating ecosystem ecology in mussel aquaculture towards increasing yield

The future of aquaculture is dependent upon research that leads the way to economically efficient yet environmentally sustainable methods of production. One approach to achieving this goal lies in understanding and managing aquaculture facilities as a food web that is embedded in the natural, spatially extended, marine ecosystem. In conjunction with the mussel aquaculture industry on the Magdalen Islands, *in situ* mesocosm experiments were conducted towards elucidating the impact of mussels on the plankton community. Mussels can potentially impact plankton communities directly through grazing and indirectly by modifying nutrient availability. The indirect effects were examined by measuring the cascading effects of mussel excretions on components of the benthic and pelagic community (ranging from benthic bacteria to mesozooplankton). In addition, short-term mesocosm experiments were conducted to observe the direct impact of mussel grazing on the plankton community structure, with an emphasis on looking at how mussels feed on its zooplankton competitors. The pending results from both experiments will provide a comprehensive picture of the mechanisms structuring plankton communities in mussel farms. The data from this project could allow for better prediction of carrying capacity of sites and may suggest management actions that could take advantage of the existing biological interactions (i.e., nutrient recycling) to increase mussel condition and production. We have titled the project AQUAMAN: AQUAculture of Mussels And Nutrients.

Sept. 2008 – Jun. 2011 • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), DFO, Société de développement de l'industrie maricole (SODIM), Moules de culture des Îles
Project team: Gregor Fussmann (U McGill), Philippe Archambault (UQAR-ISMER), Connie Lovejoy (U Laval), Chris McKindsey (DFO), Stéphane Plourde (DFO), Réjean Tremblay (UQAR-ISMER), Bruno Myrand (MAPAQ), Michel Fournier (Moules de culture des Îles)
Contact: Gregor Fussmann (gregor.fussmann@mcgill.ca)
http://biology.mcgill.ca/faculty/fussmann/aquaculture.html

Sarah Pease

Mesocosm structures in operation

Michel Giguère (DFO)

Clams marked for seeding

Assessment of various Soft-shell Clam *(Mya arenaria)* post-harvest action scenarios aimed at the recovery of harvested sites in the St. Lawrence Estuary, Quebec

The significant decline in commercial-sized (≥ 51 mm) Soft-shell Clam biomass on the North Shore since 2000 has raised concerns about the long-term survival of the species. In response, management strategies for a clam culture site were tested to promote the recovery of the resource and the development of clam culture in Quebec. The work was carried out at Cran à Gagnon (48°48'58" N, 68°56'24" W). The technique used for this project consisted of placing the nets, in two different patterns, on an intensively harvested tidal flat in order to promote the settlement of current year spat and the retention of residual and seeded clams. Sampling was carried out in the fall of 2007, 2008, and 2009, to measure demographic changes in the clams.

The results show that variations in spat (≤ 10 mm) density are attributable primarily to annual variability in reproductive success. They also show a significant increase in spat density in the plots with nets in the fall of 2007 and 2008. One year after the removal of the nets, spat densities were similar on all treatment sites. It also appears that the nets contributed to the retention of seeded clams, but prevented the settlement of clams over 26 mm from the surrounding area.

Apr. 2007 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Fisheries Science Collaborative Program (FSCP), Société de développement de l'industrie maricole, Association des cueilleurs de myes de la Haute-Côte-Nord, Comité côtier Les Escoumins à la rivière Betsiamites, Coquillages Nordiques
Project team: Sylvie Brulotte (DFO – IML), Michel Giguère (DFO – IML), Jean-Marie Bélisle (Comité côtier Les Escoumins à la rivière Betsiamites), Claudia Boisvert (Association des cueilleurs de myes de la Haute-Côte-Nord), Bernard Tremblay (Association des cueilleurs de myes de la Haute-Côte-Nord), Isabel Calderón (Société de développement de l'industrie maricole inc.) • Contact: Sylvie Brulotte (Sylvie.Brulotte@dfo-mpo.gc.ca) • www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Dispersal of seeded clams during storms in the Magdalen Islands

Significant losses have been observed after seeding of young clams. Dispersal is one factor that should be examined given that, in the Magdalen Islands, clams are seeded on a medium sand substrate. A previous project carried out in a flow channel showed that young clams burrowed into such a substrate could be dislodged at a lower level of turbulence than that reported during storms. Losses associated with storms have been documented *in situ* since 2008. Small experimental plots (40 cm x 40 cm) are seeded with 20 and 30 mm clams (500 clams m^{-2}) in early summer and covered with 4-mm mesh protective nets. Prior to an anticipated storm, the nets are removed from six of the plots and 2 to 3 plots are harvested immediately to determine the number of clams just before the storm. The remaining plots are harvested immediately following the storm. The difference between the two average densities is interpreted as loss due to the storm. The sediment dynamics (sedimentation/erosion) is also measured on the experimental plots. Losses due to storms are marginal as very little sand (< 1 cm) is eroded during the storms.

Apr. 2008 – Mar. 2012 • Funded by: MAPAQ, MDEIE, DEC, Société de développement de l'industries maricole (SODIM), CLD Îles-de-la-Madeleine
Project team: Bruno Myrand (Merinov Center),
Lise Chevarie (ISMER), Réjean Tremblay (ISMER)
Contact: Bruno Myrand (bruno.myrand@mapaq.gouv.qc.ca)

Burrowing depth of Soft-shell Clams in the Magdalen Islands

Dispersal and predation are among the factors to consider in explaining the significant losses following the seeding of young soft-shell clams. Vulnerability of clams to predation and dispersal depends largely on their depth of burrowing. The deeper they burrow, the less accessible they are to predators and the less vulnerable they are to dispersal caused by the erosion of surrounding sediments. Temporal changes in the burrowing depth of 20 and 30 mm clams have been monitored since 2008 in the Magdalen Islands. A fine graduated thread is glued to the shell of each experimental clam. The other end of the thread is attached to a metal rod. Burrowing depth is measured each week over a large part of the summer (mid-July to mid-November). The clams very quickly reach the burrowing depth they will maintain overall (< 1 week). Clams measuring 20 mm burrow 4-6 cm below the surface and clams measuring 30 mm burrow 5-8 cm below the surface.

Apr. 2008 – Mar. 2012 • Funded by: MAPAQ, MDEIE, DEC, Société de développement de l'industries maricole (SODIM), CLD Îles-de-la-Madeleine
Project team: Bruno Myrand (Merinov Center), Lise Chevarie (ISMER),
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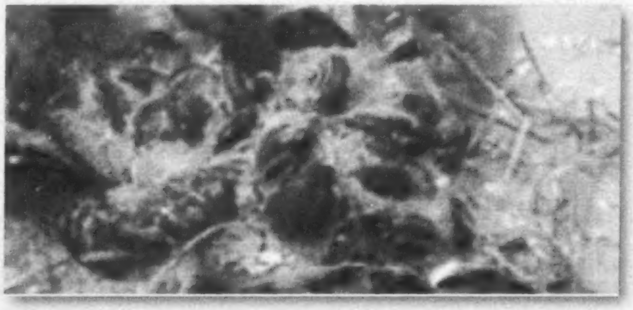
Scale-up of hatchery production of American Lobster larvae for stocking in order to support a sustainable fishery

Despite the implementation of management measures and conservation efforts by harvesters, landings of American Lobster (*Homarus americanus*) in the Gaspé region have not returned to the record highs of the early 2000s. To help the resource and ensure the sustainability of the lobster fishery in the Gaspé region, the Regroupement des pêcheurs professionnels du sud de la Gaspésie (RPPSG) and Merinov have implemented a project to scale up the hatchery production of American Lobster larvae for stocking. The project target is to produce and stock over 100,000 stage IV+ lobster larvae by 2012. The purpose of the project, carried out at the Centre aquacole marin de Grande-Rivière (Quebec), is to establish optimum protocols that make it possible to obtain an average larval survival rate of 40% at stage IV using the greenwater culture method (combination of *Artemia* and microalgae). The project also involves selection of bottoms suitable for stocking, the implementation of before-after control impact (BACI) studies of stocking success and optimization of the production methods and costs.

Mar. 2010 – Mar. 2013 • Funded by: DEC, MAPAQ, RPPSG, MDEIE, MAMROT, Université du Québec à Rimouski (UQAR)
Project team: Jean Côté (Regroupement des Pêcheurs Professionnels du Sud de la Gaspésie), Frédérique Bélanger (Merinov), Jean-François Laplante (Merinov), Louise Gendron (MPO), Équipe du CAMGR (Merinov)
Contact: Jean Côté (jeancote@bmcable.ca)

450-L cylindrical-conical tanks used for greenwater culture of American Lobster larvae Jean Côté (Regroupement des Pêcheurs Professionnels du Sud de la Gaspésie)



Stocked mussels François Bourque (Merinov-Center Îles-de-la-Madeleine)

Stocking of mussels to rebuild natural stocks in Bassin de Havre-Aubert, Magdalen Islands

It is very advantageous for mussel growers in the Magdalen Islands to obtain their spat from Bassin de Havre-Aubert. The early reproduction of broodstock makes it possible to obtain an abundance of young mussels measuring 15-30 mm by the fall. In addition, due to their genetic characteristics (high heterozygosity), they are fast growing and more resistant to stress and therefore less vulnerable to mass mortalities. Since 2001, the natural population has declined substantially, with a 98% decrease in biomass. For that reason, spat collection has been erratic and, in some years, the situation is catastrophic, resulting in major production problems. Since the fall of 2009, spat collected in Bassin de Havre-Aubert are socked and left at the site to reproduce the following summer. They are then directly seeded on the bottom. In the weeks prior to seeding, a green crab control program is implemented near the sites to be seeded using adapted traps. The mussels are also protected from predators using screened cages for several weeks after seeding. The 13,500 mussels (45-60 mm) seeded in the fall of 2010 had a very high survival rate. This practice should be adopted by mussel growers in the future.

Apr. 2009 – Mar. 2012 • Funded by: Société de développement de l'industrie maricole (SODIM) • Project team: François Bourque (Merinov-Center Îles-de-la-Madeleine), Carole Cyr (Merinov-Center Îles-de-la-Madeleine), Bruno Myrand (Merinov-Center Îles-de-la-Madeleine)
Contact: François Bourque (francois.bourque@mapaq.gouv.qc.ca)

Seeding of clams following pre-growout in the Magdalen Islands

Young clams collected using collectors are too small to be directly seeded without resulting in significant losses. A pre-growout phase is therefore required to allow clams to reach an average size of at least 20 mm. Following this stage, the clams are seeded and left to grow until they reach a market size of 51 mm. Previous experimental work on seeding has demonstrated that significant losses often continue to occur during this last step despite the pre-growout phase. Periodic monitoring (spring and fall) is conducted to monitor changes in losses. The main objective of this project is to allow clams to grow without any intervention (no monitoring) for two full years and to then assess seeding success. The average recovery rate in October 2010, 27 months after seeding, was 40.4 ± 2.7%. The clams had reached a size of 37.5 ± 0.3 mm, representing growth of 13.3 mm (or 5.9 mm yr^{-1}).

Apr. 2008 – Mar. 2011 • Funded by: MAPAQ, MDEIE, DEC, Société de développement de l'industrie maricole (SODIM), CLD des Îles-de-la-Madeleine
Project team: Lise Chevarie (ISMER), Bruno Myrand (ISMER), Réjean Tremblay (ISMER)
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Sampling the clams Lise Chevarie (ISMER)

Protective nets to prevent clam predation

Soft-shell Clam aquaculture in the Magdalen Islands is a promising sector. To limit losses by predation and dispersal following seeding, the installation of protective nets is recommended. Work has been done to test the effectiveness of the nets against predation by examining the ability of crabs to penetrate the nets. Seed plots covered with a 4 mm mesh net and surrounded by 40 cm x 40 cm frames were used. Although the crabs burrowed in the sand along the edge of the frame, the net seems to protect the clams relatively well. However, it is important that the system be carefully installed because the frames can be unstable and can leave a space that can be penetrated by predators. In 2010, tests on the refuge size for clams from predation by rock crab were initiated. The work is being carried out in the natural environment using exclosures consisting of predetermined combinations of clam and mussel sizes. The results should allow us to form an opinion on the advisability of using a protective net in the second year following seeding of clams that have reached approximately 30 mm by that time.

Jun. 2009 – Mar. 2012 • Funded by: MAPAQ, MDEIE, Société de développement de l'industrie maricole (SODIM), Université du Québec à Rimouski (UQAR)
Project team: Madeleine Nadeau (Merinov), Bruno Myrand (Merinov), Lise Chevarie (ISMER)
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Securing mussel spat in the Magdalen Islands and the impact of predation

In recent years, Magdalen Islands clam growers have had difficulty collecting spat in Bassin du Havre-Aubert. This situation has raised concerns and forms the basis of an extensive project aimed at understanding the factors affecting spat collection success in this body of water. One of the components of this project was to characterize the importance of predation on natural mussel beds, particularly on juvenile mussels. To this end, various types of exclusion cages (closed, semi-closed, and open) were installed in two natural beds of juvenile mussels (~20 mm). In 2008, the work was done directly on the natural populations, whereas in 2009 and 2010, mussels were introduced to obtain controlled densities. Overall, the results showed significant spatial variability. In the site known as Le Goulet, mussel densities in the closed and open cages were comparable. However, at the La Rivière site, significant losses of juveniles were observed. A Green Crab population is known to occur in the vicinity of this site. The Green Crab population of Bassin du Havre-Aubert increased substantially in 2010, confirming our concerns about the impact of predation on natural mussel beds.

Apr. 2008 – Mar. 2011 • Funded by: MAPAQ, Société de développement de l'industrie maricole (SODIM) • Project team: Madeleine Nadeau (Merinov), François Bourque (Merinov), Bruno Myrand (Merinov)
Contact: Madeleine Nadeau (Madeleine.Nadeau@mapaq.gouv.qc.ca)

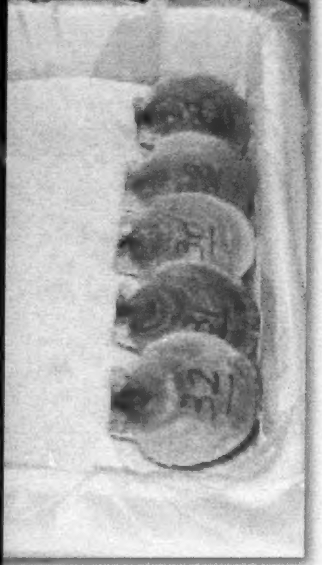
Management of commercial-scale Soft-shell Clam growout operations

The objective of this project is to develop and test a pre-growout system for small Soft-shell Clams (4-12 mm). Clams of this size have not yet reached their refuge size by the fall, often resulting in significant losses. Bins measuring 1.22 m x 2.44 m were constructed and filled with sand with a density of 5,600 clams m². Three bins were placed in the water in early July. Unfortunately, the bins were damaged and emptied by the waves produced by Hurricane Danny. After a number of technical modifications, a second test was conducted in September. Although the performance of the bins was much improved, they were once again emptied by storms in late October. The tests clearly demonstrated that bins suspended in the water column are not well suited to local severe weather conditions. With funding from the provincial government, Société de développement de l'industrie maricole (SODIM) and UQAR, a third trial was initiated in 2010 with modified bins to facilitate their handling. The results demonstrated that the technique had been improved, with the growth of the Soft-shell Clams reaching the objective of 1.06 mm/week.

Jun. 2009 – Sept. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Société de développement de l'industrie maricole (SODIM), MAPAQ, UQAR, ISMER • Project team: Sylvain Lafrance (SODIM), Robert Vaillancourt (SODIM), Julie Pariseau (SODIM), Bruno Myrand (MAPAQ), Réjean Tremblay (ISMER), Lise Chevarie (ISMER), Guillaume Werstink (MAPAQ-UQAR) • Contact: Sylvain Lafrance (sodim@sodim.org)

Sandbox for farming clams

SODIM



Scallop shipping container Merinov

Project in Quebec to increase the shelf life and vitality of scallops shipped live to market

The sale of live in-shell scallops is an important market for the Quebec scallop aquaculture industry. Maintaining scallop vitality during and after shipment is a critical factor in maintaining customer confidence and promoting the development of North American markets. However, keeping scallops out of the water for four to five days after their removal from the aquaculture site poses a major challenge. A good assessment of scallop vitality prior to shipment is critical to ensuring they can survive transport. The validation of predictive indices of the shelf life would be particularly important in order to be able to offer buyers guaranteed shelf life and product quality.

A project in Quebec is designed to test the predictive value of various physiological indices for assessing the transportability and shelf life of scallops shipped live to market. These indices were determined on various groups of scallops shipped at different times of the year and in accordance with different handling and packaging protocols.

Oct. 2009 – Dec. 2010 • Funded by: Société de Développement de l'Industrie Maricole (SODIM)
Project team: Sophie Gauthier-Clerc (UQAR), Laurent Girault (Merinov), Karine Berger (Merinov), Culti-Mer inc.
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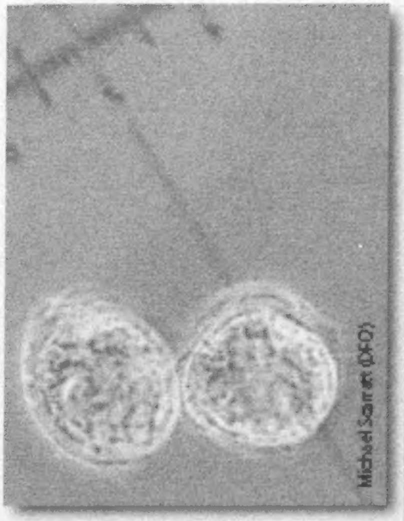
Validation of a scallop spat holding procedure

When bivalve transfer requests are made, a holding period is regularly recommended to minimize the ecological risks. The 48 h holding time required for adult organisms is based on data from the literature and is designed to eliminate live phytoplankton species from the feces and pseudofeces and from the intervalve water of the organisms to be transferred. In the case of spat, a holding time of 48 h is always recommended. However, the small size of the organisms would suggest that a shorter holding period would be sufficient and would still be effective. Reducing the holding time would have benefits in terms of reducing stress in spat prior to its transfer in conditions that will expose it to air for several hours.

The objective of this project is to validate the effectiveness of a scallop spat holding time of less than 48 h. The work includes laboratory experiments and industry verification of a high-performance filtration system. The results are expected in late 2011.

Apr. 2009 – Dec. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Société de développement de l'industrie maricole (SODIM)
Project team: Michael Scarratt (DFO), Sophie Gauthier-Clerc (ISMER-UQAR), Madeleine Nadeau (Merinov), Marie-Gil Fortin (ISMER-MAPAQ)
Contact: Michael Scarratt (michael.scarratt@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm


Michael Scarratt (DFO)

Toxic phytoplankton found in transferred scallop stocks

Nathalie Moisan (Merinov)

Plankton net

Monitoring of scallop toxicity as a function of the presence of toxic phytoplankton and relative to mussel toxicity on suspended culture sites

The main objective of this project is to assess the contamination dynamics of scallops cultured in Baie de Gaspé and Baie des Chaleurs as a function of the presence of toxic phytoplankton in the water column. The correlation between a toxic episode in mussels relative to scallops and the necessary time required for detoxification will also be evaluated. The potential synchronization of contamination and detoxification of the two bivalves is believed to have a predictive value for estimating the commercial risk of scallop harvesting when toxicity is detected in mussels harvested near a scallop culture site.

Weekly sampling of mussels and scallops was conducted from July to November 2010 on four shellfish aquaculture sites in the Gaspé Peninsula. Analyses of toxins (Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), and Amnesic Shellfish Poisoning (ASP)) in the tissue of the two bivalves were conducted. For each site and sampling period, the physicochemical parameters of the water were measured. The taxonomic analysis of the phytoplankton species sampled is currently under way. The results of this project are expected in May 2011.

Jun. 2010 – May 2011 • Funded by: Société de développement de l'industrie maricole (SODIM)
Project team: Michael Scarratt (DFO), Sophie Gauthier-Clerc (ISMER-UQAR), Nathalie Moisan (Merinov), Marie-Gil Fortin (ISMER-UQAR), Jean-Philippe Hébert (Ferme marine du Québec Inc.)
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American Oyster *(Crassostrea virginica)* suspension culture trials in lagoons and open water in the Magdalen Islands

Since the late 1990s, there has been considerable interest among oyster growers in the Maritimes in developing/adapting high-performance oyster culture techniques. The commercial size of oysters grown in floating bags and on lines is achieved in less than four years compared to seven years in the case of bottom culture. In the spring of 2010, a project was initiated to test three suspension culture techniques: oysters attached to vertical longlines, oysters attached to horizontal longlines and lantern nets. The project involves assessing the biotechnical potential of oyster culture in the Magdalen Islands in lagoons and in open water. The results for the three techniques used are very encouraging. Between June and October, growth of 20 mm was observed in 30 mm oysters grown in lagoons compared to 15 mm in oysters in Baie de Plaisance grown 7 m below the surface. Large numbers of mussels and hydrozoans attached themselves to both the structures and oysters. When the structures touch the bottom, oyster survival is affected. The project will continue until 2013, and it is being carried out in partnership with two clam growers interested in diversifying their production.

Apr. 2010 – Mar. 2013 • Funded by: MAPAQ, Société de développement de l'industrie maricole (SODIM)
Project team: Carole Cyr (Merinov), Jean-François Laplante (UQAR-MAPAQ), Moules de Culture des Îles, Moules du Large
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Sea Scallop (DFO)

Assessment of the impact of the mechanization of ear hanging operations on growth and survival of Sea Scallop

The economic viability of suspension culture of Sea Scallop *(Placopecten magellanicus)* to commercial size has not yet been demonstrated in Quebec. The labour costs of this farming strategy are high, resulting in significantly higher production costs for commercial size scallops. However, Japan has developed equipment to mechanize a number of operations associated with ear hanging culture of Japanese Scallops *(Patinopecten yessoensis)*. If effective for Sea Scallops, this equipment would substantially reduce production costs. The project was initiated in 2007, with the following objectives: i) to assess the impact of three new machines acquired to mechanize ear hanging culture operations on scallop growth and survival; ii) to characterize scallop vitality at each of the main steps in the production process; and iii) to assess the labour requirements with and without mechanization. The three machines are a washer-sorter, mimitsuri (machine that mechanizes the piercing and installation of the scallops on the culture lines), and ear-hung scallop washer. The use of these three machines had no negative impact on scallop survival.

Apr. 2007 – Mar. 2011 • Funded by: Société de développement maricole (SODIM), programme DTM d'Halieutec
Project team: Carole Cyr (Merinov), Madeleine Nadeau (UQAR-MAPAQ), Jean-François Laplante (UQAR-MAPAQ), Culti-mer inc. • Contact: Carole Cyr (carole.cyr@mapaq.gouv.qc.ca)

Samantha Richman (UQAR)

Captive common eider

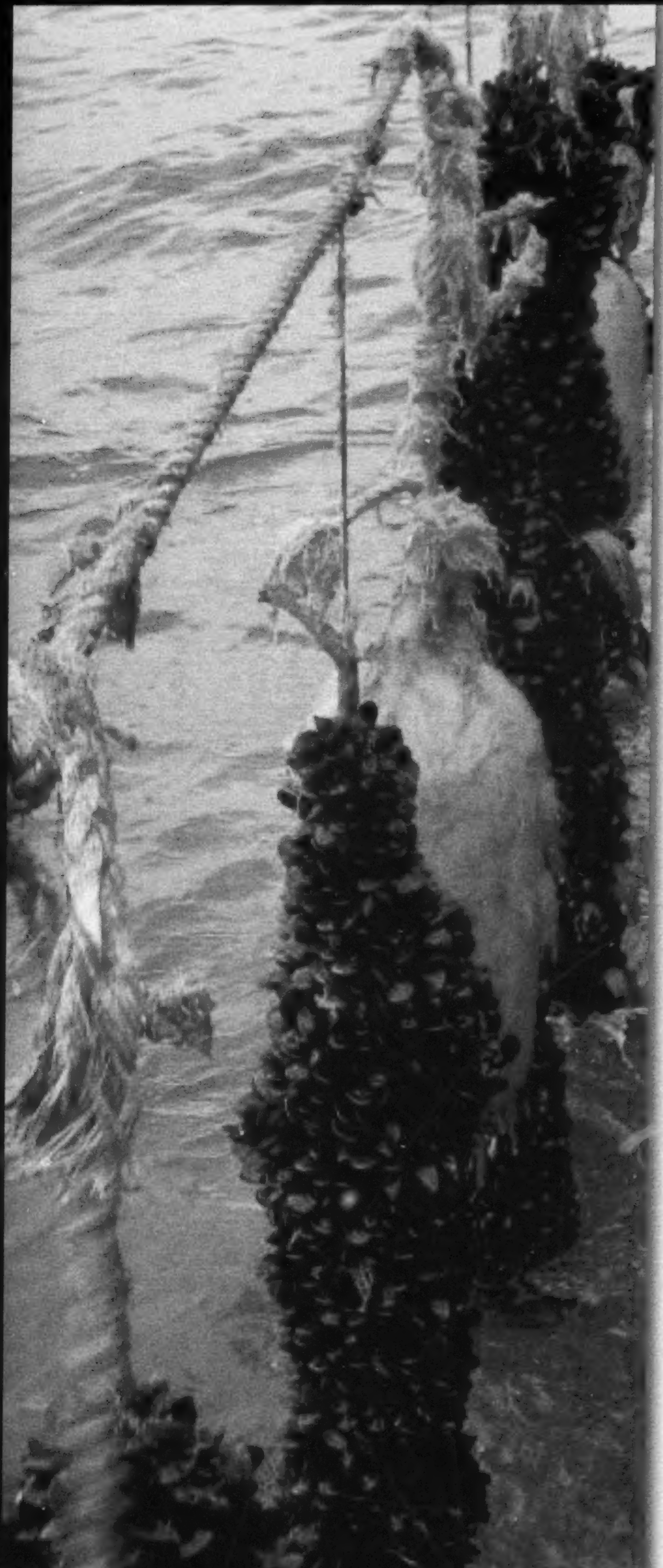
Sea duck predation on mussel farms: developing non-lethal methods of exclusion

Predation by migrating sea ducks has become a challenge to mussel growers worldwide. Mussels are the principle prey item for sea ducks, like Common Eiders, Scoters, Long-tailed Ducks and Scaup, which take advantage of mussel farms that provide a highly abundant and easily accessible food source.

Methods to "scare" ducks off mussel farms have included loud recordings, pyrotechnics, shooting, chemical deterrents, or chasing with boats; all of which have had limited success. The installation of exclusion nets to physically prevent sea ducks from entering mussel farms have been the most successful; however, nets are expensive to install and maintain, and have the potential to entangle fish, diving birds, and mammals, causing conflicts with conservation and fishery regulators.

With international collaboration between the Norwegian Institute for Nature Research (NINA), University of Quebec at Rimouski (UQAR), and Fisheries and Oceans Canada (DFO), researchers at the Maurice Lamontagne Institute (IML) are studying the underwater feeding behavior of captive sea ducks on mussel ropes, and will be developing and testing a conservation-friendly and cost-effective deterrent that limits entanglement while protecting mussel stocks. These experiments with captive sea ducks will provide critical information for the development of useful methods to exclude predatory ducks from mussel farms.

Jan. 2010 – Dec. 2012 • Funded by: Research Council of Norway (RCN)
Project team: Samantha E. Richman (UQAR), Magella Guillemette (UQAR), Elisabeth Varennes (UQAR), Svein Are Hanssen (NINA Norway), John Bonardelli (Shellfish Solutions Norway), Chris McKindsey (DFO) • Contact: Samantha Richman (Samantha.Richman@dfo-mpo.gc.ca)



Mussel culture ropes Madeleine Nadeau (Merinov)

Stabilization of anchors for clam culture lines

Several years ago, clam growers of Baie de Cascapédia were the first to report problems associated with the use of cement blocks to anchor the ends of shellfish culture lines. Some of the blocks are displaced, no doubt due to the rigorous hydrodynamic conditions, and become entangled in adjacent lines. This problem, common on exposed production sites, is likely to grow with the development of new shellfish farms in Baie de Plaisance in the Magdalen Islands. In the event of the cessation of operations, the restoration of production sites would be very difficult in cases where cement block anchors are placed on substrates having a grain size greater than that of silt. It appears that it should be possible to replace concrete blocks with other types of anchors, such as Japanese anchors, screw anchors and Manta Ray anchors. The purpose of this project is to test and compare the holding capacity of the various types of anchors for different substrates as an alternative to anchors consisting of a cement block or series of cement blocks.

2009 – 2011 • Funded by: Société de développement maricole (SODIM), Merinov
Project team: Daniel Fournier (SODIM), C. Forest (MAPAQ – DRG),
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New mussel spat collection strategy in the Lower North Shore: collectors in the form of gillnets

The production of mussels to commercial size involves a critical step, namely the procurement of mussel spat. To that end, efforts have been focused on optimizing mussel spat collection structures. This project proposes a comparison of conventional collectors with collectors in the form of gillnets. The objective of this project is to develop a more high-performance mussel spat collection system that is better adapted to prevailing conditions on the Lower North Shore and that could increase the supply of mussel spat and reduce costs associated with this step in the production process.

Apr. 2010 – Apr. 2012 • Funded by: Société de développement maricole (SODIM),
DFO – Aquaculture Innovation and Market Access Program (AIMAP)
Project team: Andrée-Anne Lachance (Merinov), Robert Lagué (SODIM)
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Testing of an approach to improve yields of spat and market mussels by reducing fall-off losses

Mussel culture has been carried out off the Magdalen Islands in Baie de Plaisance since 2007. Initial harvest data show lower than expected yields. Losses due to fall-off of spat or market mussels are observed when the lines are raised for the purpose of either adding buoys or harvesting. A project was launched to reduce losses due to fall-off using various collection approaches and various socking materials. The objective of the project was also to increase the knowledge of the phenomenon of mussel fall-off under open-water culture conditions.

Jun. 2010 – Jun. 2012 • Funded by: Société de développement maricole (SODIM),
Innovamer
Project team: Madeleine Nadeau (Merinov), François Bourque (Merinov),
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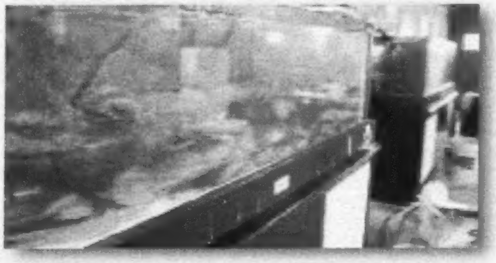
Development of a new approach for holding farmed sea scallops in seawater tanks

The maritime regions of eastern Canada are suited to marine aquaculture and the culture of various species of shellfish, including Sea Scallops (*Placopecten magellanicus*). In recent years, growers have been farming this species in Quebec using spat produced in hatcheries or collected in the wild. They sell their scallops live in the shell. This allows them to differentiate their product from fished scallops and imported products. Markets for scallops are often located at large distances from production sites, which complicates the sale of live scallops. Some suppliers would be willing to sell live scallops if they were able to keep them in holding tanks. The purpose of this project is to develop a suitable protocol for holding live scallops in closed-system tanks, filled either with natural or artificial seawater, and to determine the life span and changes in quality (i.e., taste, texture, vitality) of sea scallops held in holding tanks.

Apr. 2010 – Apr. 2011 • Funded by: Société de développement maricole (SODIM), DFO – Aquaculture Innovation and Market Access Program (AIMAP)
Project team: Andrée-Anne Lachance (Merinov), Marcel Driscoll (Pec-Nord inc.), Philippe Labadie (Aqua-Labadie enr.) • Contact: Andrée-Anne Lachance (andree-anne.lachance@partenaires.mapaq.gouv.qc.ca)



Scallops in the lab (Merinov)

Estimating fall-off of mussels cultured on self-operating collectors

In Carleton (Chaleur Bay, Quebec) some mussel farmers use the self-operating collector, which does not require the manipulation of mussel density over the grow-out period, to culture mussels. In areas where spat density is high and completely covers the collectors, the mussel density on collectors decreases via a self-thinning process. There is almost nothing known on relative differences between mussel culture on socks and self-operating collectors. The goal of this project was to gain information on how best to estimate and simulate fall-off from the self-operating or autocollectors. The rate of fall-off with autocollectors can only be estimated using computer simulations as divers find no mussels on the bottom only crushed shell in traps beneath longlines (crabs enter the traps and crush the mussels). Mussel fall-off from self-thinning can be estimated over the course of grow-out through two possible approaches. The goal of this project was to determine which approach accurately estimated mussel fall-off.

The information gained from this project will allow researchers to compare the input rates of organic matter to the bottom (fall-off) between both mussel growing systems. Results show no evidence of non-linearity in the relationship between biomass and population density, indicating that individual growth is not dependent on population density. This information will help determine the appropriate method for calculating mussel fall-off.

Apr. 2008 – Mar. 2009 • Funded by: DFO – Program for Aquaculture Regulatory Research • Project team: Marcel Fréchette (DFO)
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Merinov

Scallop spat

Risks associated with scallop spat transfers from the Magdalen Islands

A number of aquatic invasive species have been observed in the Magdalen Islands since 2003: Green Alga (*Codium fragile ssp. tomentosoides*); Green Crab (*Carcinus maenas*); Japanese Skeleton Shrimp (*Caprella mutica*); and more recently, Golden Star Tunicate (*Botryllus schlosseri*), which has been discovered in several bodies of water in the Magdalen Islands; as well as the Vase Tunicate (*Ciona intestinalis*), which has been reported at Cap-aux-Meules and on a scallop shell in the Havre-aux-Maisons lagoon. Lacy Crust Bryozoan (*Membranipora membranacea*) also occurs throughout the islands. In 2008, firms applied for permits to transfer scallop spat from the Magdalen Islands to the Lower North Shore and Gaspé Peninsula, but the applications were denied due to the risk of potential introductions of invasive species into the receiving environments. The objective of this project is to facilitate the acceptability of applications to transfer scallop spat from the Magdalen Islands to other maritime regions by identifying undesirable species and testing the effectiveness of a sanitation protocol designed to reduce the risk of introduction of invasive species.

May 2009 – Dec. 2010 • Funded by: Société de développement maricole (SODIM), DFO – Aquaculture Collaborative Research and Development Program (ACRDP)
Project team: Bernard Sainte-Marie (DFO), M. Nadeau (Merinov), N. Simard (DFO), M. Bourgeois (Culti-mer inc.), H. Bourdages (DFO), S. Gauthier-Clerc (MJ-CAMGR)
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Mussel harvesting

Marcel Fréchette (DFO)

Glued oysters Norbert Thibodeau

Multipurpose closed-system shellfish holding facility

La Maison Beausoleil Inc.

The objective of this two-year project was to establish a multipurpose closed-system shellfish holding facility that used new technology (SKIM) developed in France. The system removed bacteria and dissolved organic matter while aerating and circulating the water. The project proponents have developed a shellfish holding and depuration facility that minimizes the risk of introduction of diseases and invasive species and allows for the implementation of a more effective, more flexible product certification program. The application of the closed-system concept, the design of the holding tanks, the control of water flow, the laboratory certification and the depuration strategy have all been successfully completed.

Jul. 2008 – Mar. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Ministry of Agriculture and Aquaculture of New Brunswick, Atlantic Canada Opportunities Agency (ACOA), Northern Economic Development Fund of New Brunswick
Project team: Amédée Savoie (De la Maison Beausoleil), Léon Lanteigne (De la Maison Beausoleil), Armand Lejeune (EMG Aquaculture)
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Optimization of the horizontally glued oyster culture technique

This one-year project improved the oyster gluing process by developing technology for drying oysters, assessing the use of warm glue, and developing a floater for the glued oyster rearing structure. Results showed that the transfer of glue from the cartridge to the oyster shells occurred via compressed air provide better control and greater speed in applying the glue. An oyster dryer was constructed to dry the oysters. The methodology for horizontal gluing is now established for enterprises wishing to use this technique. The manpower is well trained and the tools will be in place to support commercialization. Commercial yields are very promising.

Apr. 2009 – Mar. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Ministry of Agriculture and Aquaculture of New Brunswick, NRC Industrial Research Assistance Program (NRC-IRAP)
Project team: Norbert Thibodeau (Brantville Aquaculture Ltée.), Denis Thibodeau (Brantville Aquaculture), Jacques Mallet (NBDAA), Sylvio Doiron (NBDAA), André Mallet (Mallet Research Services) • Contact: glen10@nbnet.nb.ca

Ecosystem-level effects of bivalve aquaculture activities: hydraulic rake impacts

An upcoming aquaculture activity in Québec (and elsewhere) is the development of Soft-shell Clam (and related) farming in intertidal or shallow subtidal areas. The impacts from this type of farming are likely to be associated with harvesting as this is done by hydraulic rake. To this end, a study was done in Quebec in 2003 by Lizon Provencher to evaluate the impacts of this activity and the recovery of the benthic communities under local conditions (sandy sediments in low energy systems), but it has not been published. This project focussed on the analysis, writing and publishing of the results of the research on the impacts of hydraulic dredge harvesting of Soft-shell Clam on benthic communities and the recovery of the communities over a 1 year period. A hydraulic rake was used to harvest Soft-shell Clam by sampling 3 experimental and 3 reference sites immediately prior to and following harvest and at 1, 4, 12, and 52 weeks post-harvest in both the spring and fall. In short, the abundance, biomass and richness of organisms > 1 mm were decreased by harvesting operations in the fall but not in the spring and organisms recovered within 1 year. The abundance of large organisms (other than Soft-shell Clams) was not affected by harvesting.

Apr. 2008 – Mar. 2009 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
Project team: Chris McKindsey (DFO)
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Kirsten Poulsen

Soft-shell clam

Small oyster glued on rope

Marie-Hélène Thériault (DFO)

Developing guidelines for culling cultured Eastern Oysters

According to popular opinion circulating among New Brunswick industry members, 25 to 50% of oysters should be eliminated during early grading because they are genetically inferior in terms of growth potential. This claim is based on the assumption that the floating bag technique offers equal growing conditions for all individuals; hence any variance in individual growth performance is genetically-based. Likewise when oyster seed are initially removed from the collectors and then graded to remove the 'slow' growers, there is no allowance for differing histories with regard to settlement time or density-dependent effects. This drastic grading strategy necessitates a higher investment in seed collection. Given the known annual risk of spatfall failure in key seed-producing areas, it is important that growers base their culling decision on scientifically-based information in order not to discard commercially-suitable seed.

This project will evaluate the growth performance of various size grades of oysters from the same year class originating from two different New Brunswick seed sources. Four size grades of oysters will also be reared using two grow-out systems (i.e., floating bags and rope-grown) and exposed to different localized environmental conditions (e.g., offshore vs. inshore wave activity). Comparing the growth and survival profiles of these various size groups will allow us to determine an appropriate strategy for identifying and culling true "slow" growers.

Apr. 2009 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), L'Étang Ruisseau Bar Ltd, Shippagan, NB
Project team: Marie-Hélène Thériault (DFO), Simon Courtenay (DFO/Canadian Rivers Institute), André Mallet (L'Étang Ruisseau Bar Ltd.), Claire Carver (L'Étang Ruisseau Bar Ltd.)
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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

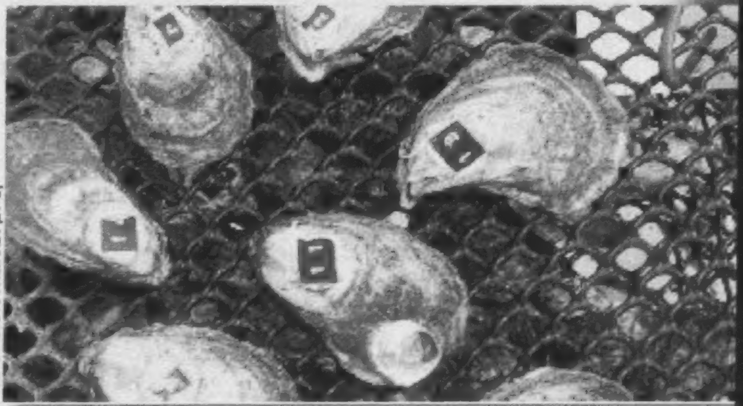
Optimizing shell growth performance and quality of near market-size oysters

This study evaluated the growth performance of various size classes of near market-size oysters deployed in different grow-out systems and environmental conditions. Fouling-control techniques and grading strategies were also investigated with the aim of augmenting the production of market-size oysters.

Oyster growth trials suggested that the growing conditions in the inshore zone were superior (i.e., higher temperature and particulate organic matter) to those in the offshore zone. Poor growth of the 50-55 mm size group relative to the three smaller size groups in the offshore zone was tentatively attributed to shell damage associated with wave exposure. Fouling-control trials indicated that brine-dipping followed by 24 h air exposure was effective in eliminating oyster spat and juvenile mussels. Mussel fouling on gear was consistently lower in warmer inshore zones where water temperature exceeded 25°C. Finally, this study indicated that the shells of >50 mm oysters were negatively impacted by mechanical grading. Bags left untouched over a 2 yr period yielded a similar or higher number of market-size oysters than those graded in the fall or the spring, but the oysters had a higher incidence of boring-sponge infection.

Apr. 2007 – Mar. 2009 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), L'Étang Ruisseau Bar Ltd.
Project team: Marie-Hélène Thériault (DFO), Simon Courtenay (DFO/Canadian Rivers Institute), André Mallet (L'Étang Ruisseau Bar Ltd.), Claire Carver (L'Étang Ruisseau Bar Ltd.) • Contact: Marie-Hélène Thériault (Marie-Helene.Theriault@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Oysters labeled to monitor growth performance



Marie-Hélène Thériault (DFO)

Comparison of an offshore and inshore site for oyster aquaculture using the French string technique in the Baie des Chaleurs

In New Brunswick, the Eastern Oyster *(Crassostrea virginica)* has been cultured in suspended gear such as floating Vexar™ bags and Dark Sea™ trays, which contribute to reducing the time needed for oysters to reach market size (shell length 65-75 mm for cocktail category or >76 mm). The gear is typically suspended from longlines but during the winter months they are lowered to avoid the ice. Another oyster suspension culture technique developed in Mediterranean France (Étang de Thau) was slightly modified and tested in northern New Brunswick with results that rival those of the techniques presently practiced in the area. The French string technique consists of gluing oysters on strings with a special cement mixture and hanging the strings vertically from a raft anchored on the bottom. The modified technique still requires that oysters be glued on strings with the string held horizontally in a rigid frame. In 2009, a new study was launched to assess the performance of oysters that are glued on strings and cultured in suspension on two leases: 1) an exposed offshore environment near Stonehaven, New Brunswick; and 2) a sheltered inshore environment in Caraquet Bay, New Brunswick with respect to their ability to rapidly attain market size. Also, oceanic parameters such as currents and temperature were monitored at both sites. In New Brunswick, culturing oysters offshore had not been investigated prior to this study. The growth rate of oysters grown offshore is not as fast as those cultured inshore; nonetheless, oyster offshore culture can be done.

Apr. 2009 – Mar. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) • Project team: Leslie-Ann Davidson (DFO)
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Memory Card
DC-9048

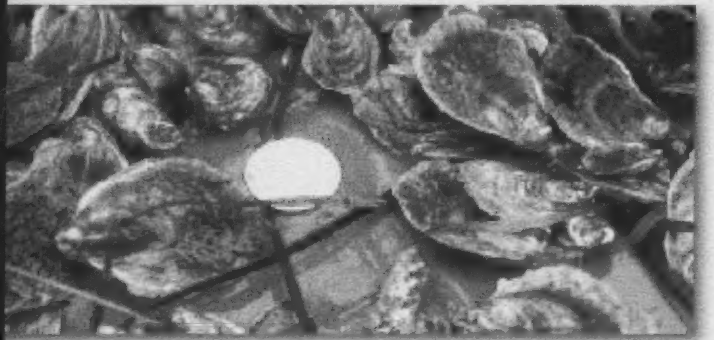
Oyster valve activity measurement Luc Comeau (DFO)

Winter physiology of the American Oyster

We are monitoring various chemical parameters in the tissue of American Oysters *(Crassostrea virginica)* over-wintered at sea, in tanks, and in cold storage. We selected parameters likely to cause physiological stress and to alter the flavour of the oysters. We are also studying valve opening behaviour using Hall elements attached to the shell. Our preliminary results suggest that, during winter, the valves open almost imperceptibly in oysters held at sea and in tanks. In the spring, valve activity is triggered when the water temperature reaches 1 to 7°C, depending on the individual. Valve activity does not appear to be related to chlorophyll-a fluctuations in the water. Acidification, increased osmolarity, and buildup of ammonia in intravalve water were noted during the winter. This was much more pronounced in oysters held in cold storage than in the other two groups. Digestive gland lipids were the most important energy reserve used by the oysters during winter.

Feb. 2010 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), L'Étang Ruisseau Bar Inc.
Project team: Élise Mayrand (U of Moncton), Luc Comeau (DFO), André Mallet (L'Étang Ruisseau Bar Inc.)
Contact: Élise Mayrand (elise.mayrand@umcs.ca) • www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/projects/projects-eng.asp

American Oyster breeding program in NB



One-year-old oysters Chantal Gionet

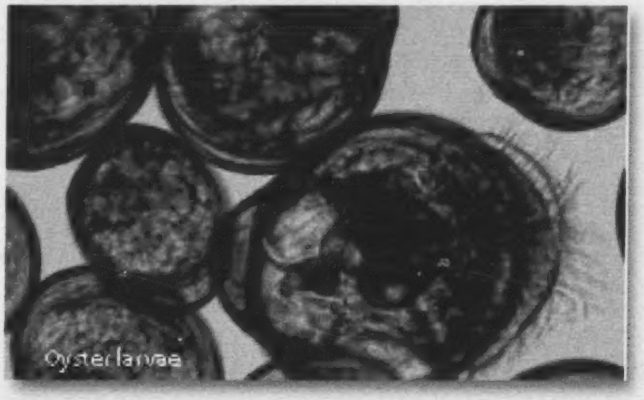
Over the last 5 years, the Coastal Zones Research Institute (CZRI) began a genetic selection program to improve performance of the American Oyster *(Crassostrea virginica)* within the framework of the Atlantic Innovation Fund (Atlantic Canada Opportunities Agency). The objective of the program was to determine, in collaboration with the industry, whether the characters selected, e.g., growth and survival, could be improved on different grow-out sites. This project allowed us to produce two cohorts of first generation (F1) in 2005 and 2007. Fourteen families were produced and put in culture, and differences in growth performances were observed between some of them. Certain families grew between 10 to 21% faster than the oyster spats collected in the wild. These results are encouraging and unique in North America. The establishment of this genetic selection program is a robust and valuable asset for the development of the shellfish industry, not only in New Brunswick, but also throughout Atlantic Canada.

2005 – 2010 • Funded by: Atlantic Canada Opportunities Agency (Atlantic Innovation Fund Program), New Brunswick Department of Agriculture, Aquaculture and Fisheries, New Brunswick shellfish growers
Project team: Chantal Gionet (CZRI), Fabrice Pernet (IFREMER/LERLR, Sète), Réjean Tremblay (ISMER/UQAR), Jean-Marie Sévigny (DFO – IML), Steven Mallet (CZRI), Gilles David (CZRI), Daniel Chiasson (CZRI), France Béland (CZRI), Mélanie Degrâce (CZRI), Mathieu Landry (CZRI), Marylène Godin (CZRI), Josée Duguay (CZRI) • Contact: Chantal Gionet (chantal.gionet@irzc.umcs.ca)

Conditioning of American Oyster *(Crassostrea virginica)* broodstock using artificial feed

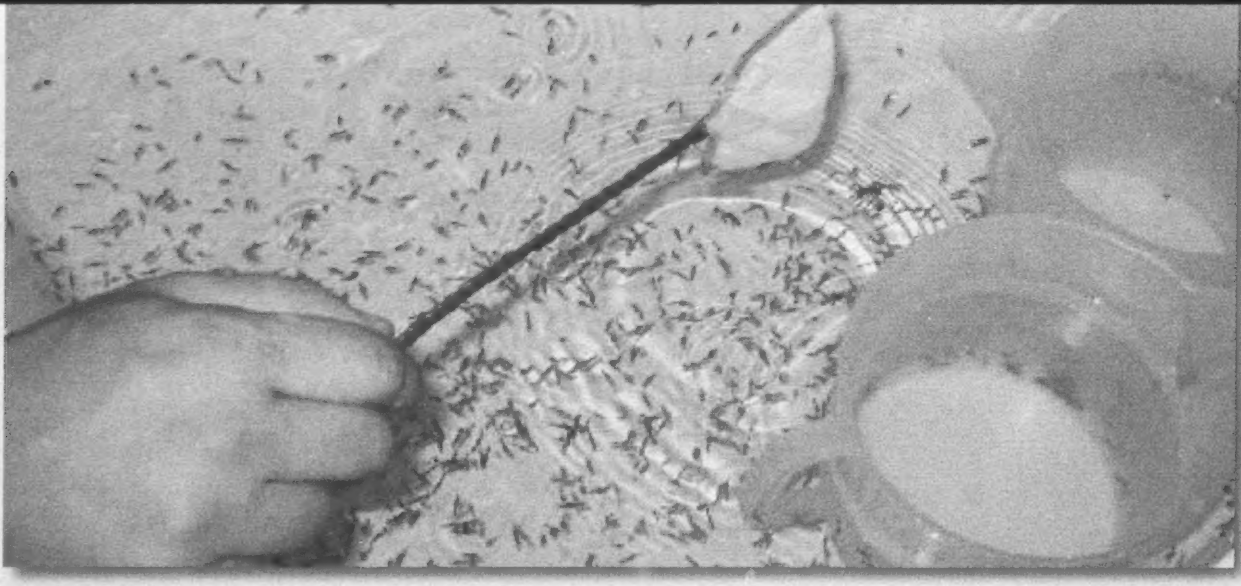
Shellfish hatchery culture relies on mass-production of live microalgae, which represents 30-50% of the hatchery operating costs. Live food production has a significant role in the conditioning of broodstock, larval development and spat grow-out of shellfish. The aim of this study was to determine the effect of dry algae and dry enrichment feed mixtures on the conditioning of adult American Oyster and performance of their progeny. The dry feed products were from Skretting's Ori-GO series. Two mixtures (90% dry algae: 10% enrichment; 70% dry algae: 30% enrichment) were compared with a live algal diet. All groups spawned successfully. Fecundity ranged from 3 to 7 million per treatment with the highest numbers observed in the live algal group. Hatching rates ranged from 80 to 90% for all treatments. Overall, the best larval growth was observed in the 90/10 group which also had the highest mortality (59%) compared with the other groups (39%). The number of competent larvae and the percentage of settling were the same for all treatments. This study indicates that oyster broodstock can be conditioned with artificial feed, produces viable larvae and reduces production costs of hatchery seeds.

Nov. 2009 – Mar. 2011 • Funded by: New Brunswick Department of Agriculture, Aquaculture and Fisheries, Skretting North America
Project team: Chantal Gionet (CZRI), Mélanie Degrâce (CZRI), Mathieu Landry (CZRI), Steven Mallet (CZRI), Marylène Godin (CZRI), Josée Duguay (CZRI)
Contact: Chantal Gionet (chantal.gionet@irzc.umcs.ca)



Oyster larvae

Chantal Gionet



Rémy Haché (CZRI)

Lobster stage IV

Stocking lobster as a tool for increasing stocks

The Maritime Fishermen's Union (MFU) and its partners have initiated a project to determine the potential of stocking stage IV lobster *(Homarus americanus)* larvae to maintain and improve lobster stocks. The MFU has established a partnership with the Coastal Zones Research Institute (CZRI) for this purpose. The mandate of the CZRI is to develop effective techniques that are easily transferable to fishermen's groups wishing to produce their own larvae. The CZRI must also produce a sufficient number of larvae for before-after control-impact (BACI) studies in order to assess stocking as a tool for increasing lobster stocks in various regions. The CZRI researchers have developed culture techniques and a feeding strategy to improve the growth and survival of stage IV larvae. Larval production rose from 1,500 in 2002 to over 350,000 in 2008. Since 2004, with the number of larvae produced, it has been possible to conduct BACI studies in three different regions. These studies have confirmed that stocking is an effective tool, contributing to increasing stocks. Work is ongoing in order to continue to improve culture techniques.

Apr. 2002 – ongoing • Funded by: Homarus Inc.
Project team: Rémy Haché (CZRI), Yves Hébert (IRZC), Caroline Roussel (IRZC), Rémi Benoit (IRZC), Martin Mallet (Homarus Inc.)
Contact: Rémy Haché (remy.hache@irzc.umcs.ca)

Impact of epibiont control treatments on the survival and condition of American Oysters

We compared the effects of two epibiont control treatments on survival and condition in American Oyster *(Crassostrea virginica)*. Hot-water treatment conditions were set at 60°C for 15 s. Mortality was higher in juvenile oysters subjected to hot-water or dessication treatment than in adults subjected to the same treatments. The effect of hot-water treatment on juveniles varied over time: mortality reached 50% in June compared to 11% in August. Mortality remained below 5% in adult controls, in adult oysters subjected to dessication treatment and in adult oysters subjected to hot-water treatment. The treatments did not affect shell growth or tissue condition in either juveniles or adults. The destabilization of lysosomal membranes in red blood cells was of little use as an early indicator of stress in oysters because it was too sensitive to various physiological or environmental factors.

May 2008 – Dec. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Acadian Aquaculture
Project team: Luc Comeau (DFO), Elise Mayrand (U of Moncton), Maurice Daigle (Acadian Aquaculture)
Contact: Luc Comeau (luc.comeau@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/projects/projects-eng.asp

Technologies essential to commercializing lobster larvae hatcheries

In 2010, the Coastal Zones Research Institute (CZRI), in collaboration with its commercial partner, Homarus Inc., began a major applied research project aimed at reducing the cost of producing stage IV lobster *(Homarus americanus)* larvae for use in stocking. The project is funded in part by the National Research Council of Canada (NRC, Industrial Research Assistance Program). Having demonstrated in a previous project that the stocking of lobster larvae has a positive impact on wild stocks, Homarus Inc. must now make larvae production a viable commercial operation. The CZRI is currently developing technologies for achieving commercially viable production costs by using its expertise in the area of marine organism larval production. Technologies include the installation of tanks specifically for the culture of lobster larvae, an automatic collection system, the development of standardized techniques, and the improvement of broodstock management. On completion of the project, Homarus Inc. and its commercial partners will be in a position to implement the first commercial hatcheries devoted to the production of lobster larvae for stocking.

Jun. 2010 – Dec. 2011 • Funded by: Homarus Inc., National Research Council Canada (Industrial Research Assistance Program), New Brunswick Department of Agriculture, Aquaculture and Fisheries (Total Development Fund), New Brunswick Regional Development Corporation (Northern Economic Development Fund)
Project team: Rémy Haché (CZRI), Yves Hébert (CZRI), Caroline Roussel (CZRI), Rémi Benoit (CZRI), Martin Mallet (Homarus Inc.)
Contact: Rémy Haché (remy.hache@irzc.umcs.ca)

Innovative tunicate treatment systems for mussel farming in PEI

Tunicate treatment

PEI Aquaculture Alliance

This one-year project had a number of components aimed at the development and evaluation of equipment designed to mitigate the impact of the solitary and colonial tunicate species present in mussel farms. The original objectives of the project were to develop colonial tunicate treatment systems and a platform for the treatment of various tunicate species. The final objective of the project was to develop the existing treatment equipment to the point where the pre-marketing phase could begin. The overall project objectives were met. Through the project, two innovative systems for the treatment of colonial tunicates were developed using treatment technologies that can be employed in and out of the water. A safer version of a high-pressure sprayer system already in use was developed by means of an innovative nozzle configuration. A complete equipment carrier was developed to help mussel farmers with the treatment of the various tunicate species present in their farms.

The provision of finalized, endorsed, and standardized drawings for each of the treatment systems of this project will give mussel farmers a guide to the building of new systems. These drawings will enable mussel farmers to develop new systems and to communicate their needs to the equipment manufacturers.

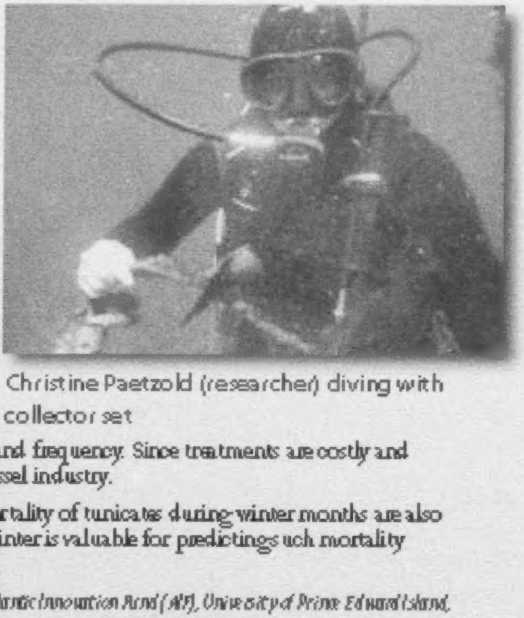
July 2009 – July 2010 • Funding: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Prince Edward Island Aquaculture Alliance (PEIAA), PEIDFARD, Fundy Engineering • Project team: Jarrod Gunn-McQuillan (PEIAA), Peter Warris (PEIAA), Jennifer LaRosa (PEIAA), Linda Duncan (PEIAA), Stephen Fortune (Blue Bucks Inc.), Carl Reynolds (Reynolds Island Mussel Company Ltd.), Wayne Chiasson (W&R Fisheries), Hal Publicover (W&R Fisheries), Jason Simpson (W&R Fisheries), Neil MacNair (PEIDFARD), Kim Gill (PEIDFARD), Brian Gillis (PEIDFARD), Peter McKelvey (Fundy Engineering) • Contact: ed@aquaculturepei.com

Monitoring for invasive tunicate eggs and larvae

Molecular assays have been successfully created that can detect eggs and larvae of five species of invasive tunicates in environmental water samples (*Ciona intestinalis, Styela clava, Botryllus schlosseri, Botrylloides violaceus*, and *Diplosoma listerianum*). These assays have a high specificity and sensitivity, and can consistently detect as little as 1 egg or larvae/450 litres of environmental water samples. These assays have been used to screen water samples for invasive tunicate propagules in waters surrounding shellfish aquaculture in Atlantic Canada in order to facilitate the early detection of new invasions and to monitor for seasonal reproduction in established invasions. This level of screening is currently assisting the PEI mussel industry in managing tunicate invasions in shellfish regions. The assays are high-throughput and are now available as a service through the AVC Shellfish Research Group.

Jan. 2007 – Sep. 2010 • Funded by: Canadian Aquatic Invasive Species Network (CAISN) • Project team: Sarah Stewart-Clark (UPEI, Atlantic Veterinary College), Jessica Willis (UPEI, Atlantic Veterinary College), Jeff Davidson (Atlantic Canada Opportunities Agency), Spencer Greenwood (UPEI, Atlantic Veterinary College)
Contact: Sarah Stewart-Clark (seclark@upei.ca)

Techniques and mitigation strategies for managing invasive tunicate species fouling aquaculture farms


Christine Paetzold (researcher) diving with collector set

Atlantic Veterinary College Shellfish Research Group

The PEI Aquaculture Alliance and the University of PEI are collaborating on an Atlantic Innovation Fund Project addressing the detection, prevention and treatment of invasive tunicates.

Our detection team is developing a rapid tunicate diagnostic field kit using tunicate DNA and RNA. The prevention team is identifying and characterizing potential anti-fouling compounds that can be incorporated into aquaculture gear.

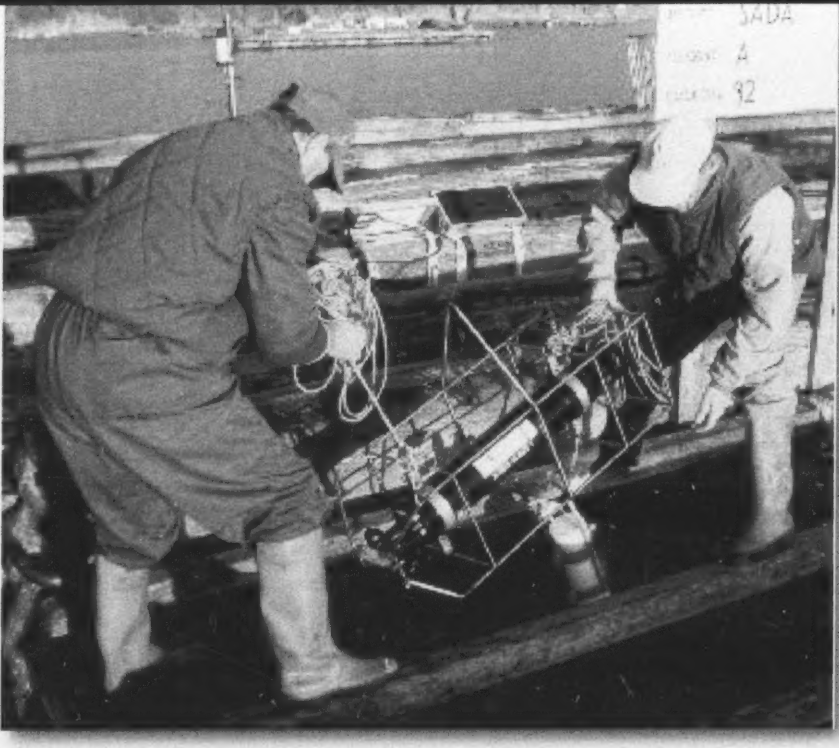
Research on mitigation strategies for tunicates on mussel aquaculture leases is being conducted by the treatment team. Projects include examining new treatment agents and methods to be applied to settled tunicates, improving mussel attachment strength while decreasing tunicate settlement, and optimizing existing treatment strategies and husbandry techniques used by mussel growers. An example of improving husbandry techniques is the determination of the optimal treatment start date and frequency. Since treatments are costly and labour-intensive, minimizing their frequency translates into decreased expenses for the mussel industry.

Histopathological changes in tunicates caused by chemical treatments and the seasonal mortality of tunicates during winter months are also being evaluated. Knowledge of why and when tunicate populations die back during late winter is valuable for predicting such mortality events and avoiding the cost of potentially redundant treatments of mussel lines in the fall.

Jun. 2007 – Jun. 2011 • Funded by: PEI Aquaculture Alliance (PEIAA), Atlantic Canada Opportunities Agency / Atlantic Innovation Fund (AIF), University of Prince Edward Island, PEI Atlantic Shrimp Corporation Inc., Aquaculture and Fisheries Research Initiative, PEI Department of Fisheries, Aquaculture and Rural Development, Fisheries and Oceans Canada (DFO) • Project team: Russ Kerr (UPEI), Jeff Davidson (Atlantic Canada Opportunities Agency), Ahmed Siah (UPEI), PEI Aquaculture Alliance
Contact: Jarrod Gunn-McQuillan (ed@aquaculturepei.com)

Update of the PEI Shellfish Aquaculture Environmental Codes of Practice (SAECOP)

The objective of this one year project was to review the PEI Shellfish Aquaculture Environmental Codes of Practice (SAECOP) and identify any gaps and updates needed to ensure the continued viability of the industry, through the maintenance of a healthy environment in which to operate in and the continued confidence of government and consumers in the industry. As a living document, the codes of practice will continue to accommodate changes in aquaculture technology and practices. There are currently 278 signatories, to the SAECOP, the majority of whom are working shellfish farmers.



Spain raft LIIST Peter Cranford

Originally put in place in 2002, SAECOP consists of guidelines, primarily for off-bottom and water-column shellfish aquaculture, which outline recommended practices and to help ensure the industry maintains: environmental responsibility, economic viability, and maximum product quality.

Oct. 2009 – Mar. 2010 • Funded by: PEI Atlantic Shrimp Corp., Fisheries and Oceans Canada (DFO), PEI Department of Fisheries, Aquaculture and Rural Development
Project team: Peter Warris (R&D, PEI Aquaculture Alliance), Crystal MacDonald (Carpe Diem Consulting)
Contact: Peter Warris (rd@aquaculturepei.com) • www.aquaculturepei.com

Production of mussels – mitigation and feed for husbandry (MUMIHUS)

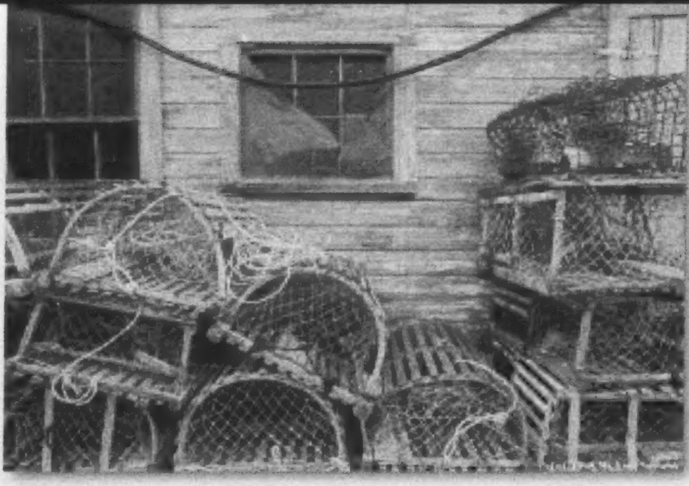
Many coastal water bodies have problems with eutrophication and hypoxia due to nutrient loading. Cultured shellfish are well known to be able to mitigate eutrophication via phytoplankton removal. A research program in coastal Denmark is aimed at culturing shellfish for nitrogen removal in the form of their tissue biomass. In addition to seafood value, this protein may be fed to farm animals such as pigs. The original fertilizer nitrogen is thus removed from the marine system, and recycled to agriculture, reducing the requirement for new nitrogen input. Both field and modeling campaigns with international teams have been established at mussel farms in the Limfjord to investigate this approach. The application of nitrogen and carbon trading to aquaculture will become increasingly important. Mitigation strategies involving this approach can be utilized in regions such as PEI where nutrient loading from aquaculture is already attenuated by mussel culture

2009 – 2011 • Funded by: Danish Council for Strategic Research
Project team: Jens Petersen (Danish Shellfish Center), Jon Grant (Dalhousie University)
Contact: Jon Grant (jon.grant@dal.ca)

Ecological Sustainability of Suspended Mussel Aquaculture (ESSMA)

The ESSMA project addresses science needs generated by maritime regulatory policies in Canada and the European Union related to ecosystem-based management. This project is designed to provide scientific knowledge, sustainability indicators, modeling capacity, sustainable ecological engineering approaches to farm management, and expertise that can meet the demands of large-scale mussel aquaculture assessments. Studies in multiple geographic settings enhance our overall predictive capacity, which lead to a more generic assessment capacity. Project objectives include the development of methods for estimating and optimizing suspended bivalve production at the coastal ecosystem-scale while maintaining ecological integrity. Sustainability issues specific to the mussel culture industry will be assessed based on observations of bivalve interactions with pelagic systems over different spatial scales (culture unit to bay) using food depletion criteria, carrying-capacity model predictions, and Integrated Multi-Trophic Aquaculture (IMTA) concepts and approaches. Farm and ecosystem model predictions will be validated using results from high resolution, bay-scale food depletion mapping. The development of IMTA concepts and approaches specific to the mussel culture industry would help to achieve a balance between commercial production and environmental sustainability.

Apr. 2009 – Mar. 2012 • Funded by: Fisheries and Oceans Canada (DFO), Spanish Ministry of Science and Innovation
Project team: P. Cranford (DFO), S. Robinson (DFO), M.J. Fernández-Reiriz, U. Labarta, C. Gonzalez-Castro, S. Piedracoba, X.A. Alvarez-Salgado (Consejo Superiour de Investigaciones Científicas, Instituto de Investigaciones Marinas, Spain), P. Duarte (Universidade Fernando Pessoa, Portugal), Proinsa mussel farms (Spain)
Contact: Peter Cranford (Peter.Cranford@dfo-mpo.gc.ca)



Michael Seewald

Lobster traps

Interactions of mussel aquaculture and American Lobster in Eastern Newfoundland

Lobster landings in parts of eastern Newfoundland, Canada have declined in recent years. Fishers have suggested that these declines may be the result of the growing mussel aquaculture industry in the area. This study investigates interactions between mussel (*Mytilus edulis*) aquaculture farms and American Lobster (*Homarus americanus*) populations in eastern Newfoundland. Long-term temperature data, chlorophyll-*a*, mussel biomass and meat yield as well as lobster licensing and lobster landing data were analyzed for relationships in an area with and without mussel aquaculture farms in Notre Dame Bay, Newfoundland. Lobster landings declined in both areas during the period studied as did the yield from mussel farms. It is therefore unlikely that mussel farms are the direct cause of the decline in lobster populations. Significant relationships between surface temperature and lobster landings suggest that interdecadal changes in temperature may be affecting lobster landings. Primary production as indicated by chlorophyll-*a* has been decreasing in the study area affecting food availability for both lobster populations and farmed mussels. Environmental change such as temperature and food availability may also be driving the lobster into deeper waters in search for more favourable conditions. Time lagged relationships between temperature and landings were not significant, suggesting that climatic factors influence landings through adult behaviour and not larval recruitment.

Sept. 2009 – Sept. 2010 • Funded by: Memorial University of Newfoundland and Labrador (MUN), Newfoundland Aquaculture Industry Association (NAIA), Fisheries and Oceans Canada (DFO)
Project team: Allison Foster (MUN), M. Robin Anderson (DFO), Cyr Couturier (MUN)
Contact: Cyr Couturier (cyr@mi.mun.ca)

The mussel seed project

In support of development within the blue mussel aquaculture sector, the Newfoundland Aquaculture Industry Association (NAIA) is finishing five successful years of investigation of potential and existing mussel seed sources. This initiative titled "Enhancing Sustainable Mussel Industry Production and Growth through Assessment and Removal of Constraints in Seed Supply" (aka the Mussel Seed Project) addresses one of the long-term priorities identified by our mussel growers: the assurance that a consistent supply of good quality mussel seed is readily available to the industry. The project has examined the potential for seed collection in several areas of Placentia Bay, Bonavista Bay and Notre Dame Bay.

To date, analysis of collection effort (amount of seed collected at each site), morphometric analysis (shell length, depth and width, shell strength, cavity volume, etc.), growth analysis and genetic species composition analysis (PCR analysis of "glu-5" and "ITS" DNA markers) have been performed for numerous potential and existing mussel seed sites.

This year we will be completing the evaluation of seed collected in 2008 and 2009 and compiling a comprehensive project report which will include recommendations on seed collection areas in Newfoundland.

Sept. 2010 – Mar. 2011 • Funded by: Department of Fisheries and Aquaculture (DFA), NRC-IRAP, MI, DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Canadian Centre for Fisheries Innovation (CCFI), Memorial University
Project team: Heather Manuel (MI-CASD), Tracy Granter (MI-CASD), Christopher Dunne (MI-CASD), Kiley Best (MI-CASD), Darrell Green (NAIA)
Contact: Darrell Green (dgreen@naia.ca)

Newfoundland mussels Darrell Green (NAIA)

New hydraulic systems used to handle blue mussel seed

Blue mussel seed collection, stripping, grading, and socking operations are the most costly and labour-intensive activities on a mussel farm in Newfoundland and Labrador. Seed is handled multiple times and is stored on working platforms for extended periods of time while individual pieces of equipment are installed and removed. Configuration and design of hydraulic systems used by all growers are considered inadequate for the full demands of blue mussel aquaculture. Typically, each piece of equipment has its own hydraulics package to power the equipment. A new hydraulic system was tested in spring 2009 that had the oil capacity to operate multiple hydraulic motors at any given time. This process enabled automation of the seed collection to seed socking operation and significantly reduced the cost of production. Seed collection-stripping-grading-socking trials revealed socking capacity of 250 trays per day or approximately 25,000 lbs of seed socked per day. Currently this has increased to 350 trays per day, represents an improvement of double the socking capacity over the previous process.

Jul. 2008 – Nov. 2009 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), LBA Enterprises Ltd.
Project team: Gilbert Simms (LBA Enterprises Ltd.), Scott Simms (LBA Enterprises Ltd.), John Pelly Jr. (Western Hydraulics) • Contact: Chris Hendry (Chris.Hendry@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/aquaculture/sustainable-durable/index-eng.htm

H. Murray (DFO)

Laboratory analysis of mussels

The impact of long-term holding on cultured mussels post-harvest in Newfoundland

The Newfoundland mussel culture industry is poised to undergo a period of significant expansion in production due to increased utilization of existing approved culture sites as well as the development of new sites throughout the province. This expansion will cause increased availability of harvested fresh product. In many cases the product may not immediately go to market but will be required to be held at processing facilities or other holding facilities while awaiting transport. The length of stay in a holding facility may be determined by a number of factors including the immediate availability of buyers, delays of transport due to weather or mechanical issues plus others. Unfortunately, storage of mussels over longer periods has been found to result in reduced meat yield and quality, spawning, decreased shell strength and mortality. All of these issues will cause loss in market value and ultimately loss of profit for the grower. An evaluation of the effects of long-term storage on the mussel is necessary in order to understand their causes and ultimately develop solutions to these problems.

In this study researchers are focused on the measurement of morphometrical parameters, histological features, meat quality, mortality, genotype profile, immune function and physiological stress of blue mussels under current industrial standards for long-term holding. Comparisons will be made between mussels held for specific time periods (1 week, 1 month, and 3 months) under standard conditions and those prior to harvest. Identical measurements will be made on samples of mussels harvested during different times of the year and held under similar conditions (i.e., spring, summer, fall, and winter). This work will allow researchers to provide information to growers regarding the effects of holding-stress on mussel health and ultimately information on how long mussels can effectively be kept in holding and still maintain the necessary product quality.

Apr. 2010 – Mar. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Norlantic Processors Ltd.
Project team: Harry M. Murray (DFO), Jessica Wyatt (DFO/MUN), Sharon Kenny (DFO), Kim Hobbs (DFO), Gehan Mabrouk (DFO), Terry Mills (Norlantic Processors Ltd.)
Contact: Harry Murray (Harry.Murray@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Mussel seed performance after transfer from two donor sites to a new recipient site

The mussel culture industry in Newfoundland has historically been centred on the northeast coast of the island, primarily in Notre Dame Bay. The majority of seed spat collection and grow out has occurred in this area. A recent realization that expansion of the industry is eminent has stimulated a need for new and consistent sources of high quality seed. It is thought that quality and quantity of this seed source maybe a constraint restricting expansion of the industry.

Newfoundland is known to be a zone of hybridization between two mussel species, *Mytilus edulis* and *Mytilus trossulus*. Previous work has suggested that seed from populations composed primarily of *M. edulis* would provide a more market acceptable product at harvest.

Comparisons of the performance of these species consistently show that the culture of unispecific *M. edulis* stocks have great potential to improve industry-wide production and product quality and reduce inter-site variability in market acceptable characteristics. Unfortunately, transfers of seed stock from areas containing primarily *M. edulis* into areas containing indigenous mixed-species stocks has shown that *M. edulis* do not always out-perform the indigenous mixed population. It is speculated that genetic variation within the *M. edulis* genotype may be part of the cause. It is clear that a need exists to both identify sources of unispecific or high ratio *M. edulis* stocks and to test their performance on recipient sites in order to determine their potential as donor seed stocks.

In light of these needs, a study was initiated to examine the genotypic profile, morphometrical characteristics and growth rates of two distinct new potential seed stock sources in Newfoundland and evaluate their performance at a recipient site in comparison to an indigenous seed source from the recipient site.

Performance results from the study indicated that donor sites for seed transfer operations should be evaluated individually for performance parameters and/or managed to the extent where only the best final product is made available to ongrowing and market. The feasibility of these types of evaluations on the large-scale is questionable; however, it would seem that enough data now exists from site genotyping profiles around the province of Newfoundland to allow for a good prediction of seed performance and quality based on the proportion *M. edulis* to *M. trossulus* present in the population.

Sept. 2009 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Newfoundland Aquaculture Industry Association (NAIA)
Project team: Harry Murray (DFO), Randy Penney (DFO), Marsha Clarke (DFO), Dwight Drover (DFO), Sharon Kenny (DFO), Sean Macneill (DFO), Kim Hobbs (DFO), Gehan Mabrouk (DFO) • Contact: Harry Murray (Harry.Murray@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

H. Murray (DFO)

Blue Mussel, *Mytilus edulis*

Mussel socks

H. Murray (DFO)

Sampling oceanographic characteristics of the bay

H. Murray (DFO)

Survey of seed availability and quality from a number of bays in Newfoundland

The mussel culture industry has become a significant contributor to total aquaculture production in Newfoundland. In 2009, 51 commercial mussel sites were recorded giving a total of 3689 hectares of area dedicated to production. Expansion of the industry is eminent and as a result has stimulated a need for new and consistent sources of high quality seed. It is thought that quality and quantity of these seed sources may be a constraint restricting expansion of the industry.

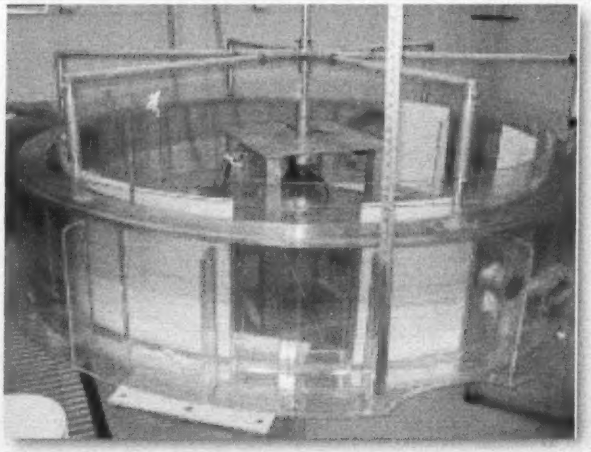
Newfoundland is known to be a zone of hybridization between two species of mussel, i.e., *Mytilus edulis* and *M. trossulus*. Comparative studies of the morphometrical characteristics of these species indicate that *M. trossulus* has lower shell and meat growth than *M. edulis* as well as increased rates of shell breakage and colour variation inconsistent with market needs. The geographical distribution of these species and their hybrids in Atlantic Canada is primarily based on genetic differences. These observations suggest that seed from populations composed primarily of *M. edulis* would provide a more market-acceptable product at harvest.

As part of a study to investigate and evaluate new potential mussel seed sources in Newfoundland, a survey was initiated to provide a general overview of the genotypic profile (species profile) and morphometrical characteristics of mussels from various selected sites around the island. Species composition of samples collected from potential seed stock sources was determined by two diagnostic markers, Me15/16 and ITS using PCR and Restriction Fragment length analysis. Standard morphological measurements were also completed for all samples. The majority of sites examined had a species composition of greater than 90% *M. edulis* for both markers. Morphometrical measurement showed considerable sample variation among sites.

Data collected from this survey will provide growers with information valuable in selecting and managing new seed collection sites.

Apr. 2006 – Mar. 2010 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Newfoundland Aquaculture Industry Association (NAIA)
Project team: Harry Murray (DFO), Randy Penney (DFO), Marsha Clark (DFO), Dwight Drover (DFO), Sharon Kenny (DFO), Sean Macneill (DFO), Kim Hobbs (DFO), Gehan Mabrouk (DFO) • Contact: Harry Murray (Harry.Murray@dfo-mpo.gc.ca) • www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Benthic transport of aquaculture tracer material


Lab Carousel: annular water-flow flume Terri Sutherland (DFO)

Predicting the dispersal of feed pellets and faecal waste through the use of hydrodynamic modeling is necessary to estimate the benthic zone of influence surrounding farm systems. Validating model predictions can help with site selection and provide research and monitoring tools for regulating the aquaculture industry. In order to accurately validate models, transport coefficients of waste material ranging in size and chemical makeup were determined using a sedimentation column and an annular water-flow flume. Sinking rates and resuspension thresholds of fish feed pellets increased with increasing pellet size. Feed pellets formed aggregate formations at lower velocities decreasing their overall speed at lower flows. At higher flows, larger pellets moved faster than smaller pellets, likely due to their subdued saltation behaviour. The sinking rates of faecal pellets appear to be 40-60% lower than those of fish feed pellets. Transport of faeces was variable within an individual experiment due to the break-up behaviour of faecal pellet texture. This study provides some information regarding resuspension thresholds for feed pellets and faecal material. With the continuance of such research it should be possible to shed further light on the dispersal patterns around fish pens and to develop methods to ensure the sustainability of the aquaculture industry.

Sept. 2009 – Mar. 2010 • Funded by: DFO – Program for Aquaculture Regulatory Research
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Video characterization of potential aquaculture impacts on hard-bottom

Although monitoring tools have been developed for benthic aquaculture assessments associated with soft-substrate settings, knowledge gaps exist regarding hard-substrate methods. The objective of this project is to identify methods for monitoring, quantifying, and evaluating potential impacts to hard-bottom substrates and increase the science knowledge base to support DFO ecosystem-based environmental regulation and decision making. High-definition videos and still photos were collected at stations along constant depth contours for a distance up to 1 km from farm netpens. Reference transects were oriented perpendicular from shore, across increasing water depths, to examine patterns of bethic community composition with depth. Additional work is required to establish reference stations as different zonation patterns exist between high-grade and low-grade seafloor slopes. Videos and images are currently being analyzed, and the information gained will be integrated with acoustic multibeam surveys to characterize the seafloor and biological communities associated with aquaculture operations. Depositional hard-bottom environments can be very complex and are sometimes made up of a mosaic of hard (rocky slopes), mixed (boulder fields), and/or compact seabeds (gravel shell-hash). A suite of technologies may be required to delineate natural and impacted seabeds of a heterogeneous nature and to determine what threshold effects of environmental change can be used practically for habitat management purposes.

Sept. 2010 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research
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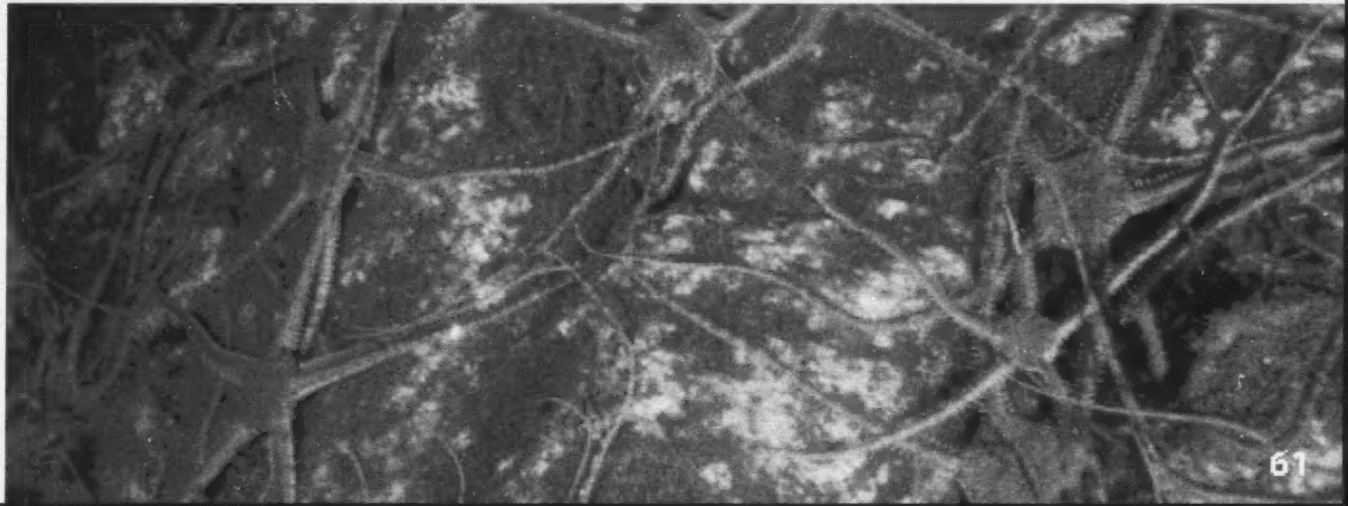
Brittle stars on a hard-substrate surface


Terri Sutherland (DFO)

Data collection in support of zone of impact modeling for Lake Huron cage farms

This project has begun the collection of data required to perform waste deposition modeling and zone of impact delineation at commercial cage sites in Lake Huron. Fine-scale bathymetric data, current speed and direction data, and farm production records were collected from three of nine commercial fish farm sites in the North Channel of Lake Huron. These data are required for DEPOMOD, which is a particle tracking model developed for and in use in the marine environment. DFO's Central & Arctic Region is testing if this tool provides accurate predictions of deposition in the freshwater environment and to modify or seek a new tool if it does not. Such a tool would permit applicants and regulators to assess the potential production capacity of a site within the assimilative capacity of the local environment.

We conducted a sensitivity analysis of the model DEPOMOD to confirm model response to changes in the input parameters. Starting with bathymetry, current data and production from an existing farm, each model parameter was then systematically varied along a range of values that slightly exceeds the range of values available in the published literature. Sensitivity analysis is a crucial first step to determine where best to focus resources for measurement of input parameters for greater model accuracy. We found that DEPOMOD is highly sensitive to changes in the coefficient of horizontal dispersion, amount of feed wasted, spacing between cages or between cage groups, and to the digestibility of feed. The model is moderately sensitive to increases in water depth below the cages and to carbon content of the feed. Within the hydrodynamic environment offered in the North Channel, the model is not sensitive to the coefficient of vertical dispersion, and the settling speeds of feed and fish waste. Some parameters affect the distribution of carbon sedimentation to the lake bed, while others impact only the magnitude of carbon flux.

DEPOMOD performance is being validated through a comparison of predictions against measured fluxes. Flux measures have been collected by deploying sediment traps around farm sites and also through the collection of sediment samples. Initial results indicate that the model over-predicts carbon sedimentation in close proximity to the cage edges and under-predicts carbon sedimentation at greater distances from the cages. No measurements of flux were obtained directly below the cages. Complex shoreline currents and uncertainty in sensitive parameters such as the coefficient of horizontal dispersion and the digestibility of feed, as well as the need for natural sedimentation rates in the area are ongoing challenges for model validation.

Apr. 2008 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research, Ontario Ministry of Foods and Rural Affairs
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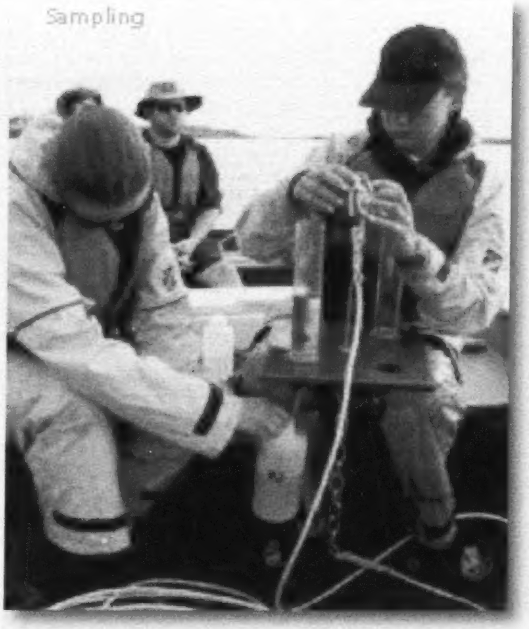
Cage site sampling

Sampling

Cheryl Podemski (DFO)

Winter sampling Cheryl Podemski (DFO)

Sampling



Cheryl Podemski (DFO)

Development of predictive modeling tools to assist with freshwater cage licensing

This project is taking advantage of a proposed expansion of the cage farm industry in Saskatchewan to test the suitability for the freshwater environment of DEPOMOD, a particle tracking model. Wild West Steelhead, already the largest Rainbow Trout cage farm in Canada, is poised to increase production through the addition of a new cage site in Lake Diefenbaker. This will be the first use of the innovative new I-cage technology in freshwater. Researchers have produced detailed bathymetric charts for the existing Cactus Bay and the proposed Kadla Coulee site, and have characterized water currents through the deployment of acoustic doppler profilers. The farm has provided detailed production records which, together with the bathymetry and current data, are being used to parameterize the model and produce deposition predictions.

Suitability testing of DEPOMOD included parameter sensitivity analysis, model parameterization and validation. Validation of DEPOMOD predictions against measured sedimentation fluxes is ongoing. Monthly during the ice-free season of 2008 and 2009, researchers deployed sediment traps around the Cactus Bay site and at upstream reference locations. DEPOMOD underpredicted waste dispersal and deposition with an overall model error (mean absolute relative error (MARE)) of +40% (N=65). Overall accuracies from the present study are less than the accuracy reported in previous research (e.g., MARE=13-20%). However, these authors only considered traps under cages for their validation. Similar MARE were obtained in the present study when considering only traps under cages. This error range is smaller than other solid waste dispersion models (e.g., GIS model accuracy with MARE of +58.1%, KK3D model accuracy +48.9%) and MERAMED (average MARE of 51%, and range 29-100%). Because the model was sensitive to coefficients of dispersion and literature values for this parameter are variable, measurements of coefficients of dispersion appropriate for typical freshwater cage sites may be an objective for future research. The effects of solids flux on sediment chemistry and benthic invertebrate community structure is being investigated through coring sediments along transects radiating from the Cactus Bay site.

The proposed Kadla Coulee site presents an opportunity to obtain good pre- and post-operational data to detect environmental impacts, and to further test DEPOMOD predictions. To create a baseline data set, water chemistry, zooplankton and phytoplankton populations as well as sediment chemistry and benthic invertebrate community structure have been monitored at the proposed Kadla Coulee site. The new farm is expected to start production in the summer of 2011, and environmental sampling will continue.

Apr. 2006 – Dec. 2009 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Wild West Steelhead
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Cheryl Podemski (DFO)

Sampling

Assessment of environmental impacts and recovery from freshwater cage culture

The impacts of cage-culture are difficult to assess because they cannot be readily quantified in the large, open systems typical of many farms. Confounding influences, such as other industrial activities, the presence of multiple cage farms, cottage or municipal wastes, local fisheries, or species introductions make it difficult to unequivocally assign responsibility for environmental degradation. An experimental approach in a controlled ecosystem where both pre- and post- aquaculture data are collected is the strongest approach to objectively evaluating the potential impacts of freshwater aquaculture on lake ecosystems.

Researchers at the Experimental Lakes Area operated an experimental Rainbow Trout farm on Lake 375 from 2003-2007. For a period of 2 years prior to production, throughout production, and for 3 years after production, L375 and the control lake (L373) have been closely monitored. During the first year of cage production, only minor changes in water chemistry occurred and no changes occurred in algal production, zooplankton, or fish communities. Changes were observed in the sediments and benthic communities under the cage, but these changes were restricted to the area directly underneath the cage. During the second year of production, changes in the sediment chemistry were again largely restricted to areas directly under the cage, while changes to infaunal invertebrate communities extended to an area 15 m distant from the cage edge. There was an increase in water column total phosphorus, and algal production also showed a significant increase through years 2-5 of production, averaging approximately 4x higher than pre-farming production. Algal production remained elevated during the first year after fish farming but declined in 2009 and returned to background levels in 2010. The zooplankton community was largely unaffected by cage culture. The Opossum Shrimp (*Mysis* sp.) population declined significantly in both L373 and L375 in 2008; the L373 population rebounded the following year but this did not occur in L375 until 2010, two years after cessation of farming. The native Lake Trout population exhibited increased growth, condition factor and abundance in response to aquaculture. The size of the Lake Trout population in L375 nearly doubled over the 5 years of aquaculture production. The response of the Lake Trout population to the removal of the farm is now being monitored to determine for how long increased growth and condition will continue. The forage fish community, which was not as closely monitored as Lake Trout, showed increased catch per unit effort for many species. The use of stable C and N isotopes to track the assimilation of cage-associated materials has shown that the wild fish community, as well as many of the invertebrate species in the lake have been utilizing waste from the cage as a food source. An isotope mixing model suggested that as much as 30% of the diet of minnows was of farm origin.

This project has demonstrated that with appropriate siting, freshwater cage aquaculture can be an environmentally sustainable activity and the project continues to make important contributions even after removal of the farm. One potential management technique that could be employed by the industry to reduce accumulation of wastes and the associated changes in invertebrate communities under farms is fallowing – to rotate production periodically between different areas to allow assimilation of wastes. This strategy is employed by the marine finfish industry in a variety of jurisdictions. The continued monitoring of the recovery of sediments under the ELA farm provides a valuable opportunity to measure the rate of assimilation of waste material and help to inform to development of fallowing practices for freshwater.

2001-2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Northern Ontario Aquaculture Association
Project team: Cheryl Podemski (DFO), Ken Mills (DFO), Paula Azevedo (DFO), Paul Blanchfield (DFO), Mike Paterson (DFO), Ray Hesslein (DFO), Michael Turner (DFO), Dave Findlay (DFO), Xin Zhang (DFO), Cynthia Wlasichuk (DFO), Sandra Chalanchuk (DFO), Lori Tate (DFO), Adam McFee (DFO), Alain Dupuis (DFO), Karen Kidd (UNB), Marilynn Kullman (UNB), Shelley Weldman (UNB), Rebekah Rooney (U of Manitoba), Kelly Hille (U of Manitoba), Michelle Wetton (U of Manitoba), Corben Bristow (U of Ottawa)
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Treatment of particulate and dissolved wastes from a flow-through aquaculture facility

Sedimentation and screening are primarily used for solid waste removal in flow-through aquaculture facilities. These physical treatment methods remove settleable solids and particulate bound nutrients from the wastewater, but they do not treat the dissolved fractions such as total ammonia nitrogen, phosphate and biochemical oxygen demand (BOD5) that can harm the receiving aquatic environment.

The Centre for Alternative Wastewater Treatment has partnered with the Haliburton Highlands Outdoors Association in Haliburton, Ontario, which operates a flow-through salmonid hatchery. The purpose of the partnership is to study the ability of a subsurface flow constructed wetland to treat the concentrated wastewater flow that is produced during daily vacuuming of the hatchery's raceways. Constructed wetlands remove suspended solids and particulate bound nutrients by sedimentation and filtration and treat the dissolved fractions of the wastewater through microbial processes of decomposition and nitrification-denitrification.

The constructed wetland has been receiving vacuumed wastewater since the autumn of 2008. The graph shown depicts average reductions of total suspended solids (TSS), carbonaceous biochemical oxygen demand (cBOD5), chemical oxygen demand (COD), ammonia, and total phosphorus and phosphate during 2009–2010 when wastewater was flowing horizontally through the system.

During 2010-2011, the wetland is being operated with vertical dosing of wastewater to improve TSS, cBOD5, and ammonia removal.

May 2008 – May 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), New Directions Research Program, OMAFRA, Ontario Trillium Foundation
Project team: Brent Wootton (Fleming College), Gordon Balch (Fleming College), Bruce Anderson (Queen's University), Chris Metcalfe (Trent University), Robin Slawson (Wilfrid Laurier University), Alison Snow (Queen's University), Lauren Sansford (Queen's University), Mike Mitzel (Wilfrid Laurier University), Cassandra Holt (Wilfrid Laurier University) • Contact: Brent Wootton (bwootton@flemingc.on.ca)
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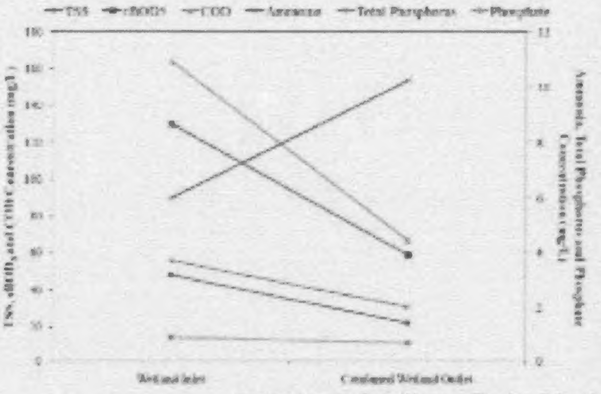
Changes in water characteristics following constructed wetland system treatment



Brent Wootten (Fleming College)

Carrying capacity modeling for bivalve aquaculture: biodeposition

Small mussel socks with and without two species of tunicates and control socks were constructed to evaluate biodeposition (sedimentation rates) associated with mussels and fouling organisms in field conditions over a 2 week period in September/October 2008. In short, biodeposition rates of mussel socks with tunicates were about double those without tunicates. Sinking rates of tunicate faecal pellets varied greatly but averaged about 2.35 cm sec^{-1}, about twice that of mussels. These data were used within an existing hydrodynamic-based depositional model - DEPOMOD - to predict benthic loading within a culture site. Benthic loading was predicted to be much greater although more restrained spatially when tunicates are present. Refinement of this and related models will ultimately allow for better predictions for aquaculture management within an ecosystem-based management framework for sustainable aquaculture.

Apr. 2008 – Mar. 2009 • Funded by: DFO – Program for Aquaculture Regulatory Research
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Chris McKindsey (DFO)

Experimental mussel sock with tunicates over sediment trap

Monitoring and modeling phosphorus contributions in a freshwater lake with caged-aquaculture

Water quality risk management for cage-aquaculture in Ontario is currently based on *in situ* sampling, meaning results are based on phosphorus concentrations at the time of measurement. The current water quality regulatory framework lacks a predictive element with which to address the dynamic nature of nutrient loadings in "open" ecosystems. The need for sustainable environmental management of cage-aquaculture farms is of primary importance if the industry is to move forward while preserving the ecological integrity of the Great Lakes.

A phosphorus mass-balance model was applied to a freshwater lake with cage-aquaculture on Manitoulin Island, Ontario. The objectives of the study were to: 1) determine the relative contributions of phosphorus from other sources (e.g., dwellings, tributaries, groundwater, inlet exchange, atmosphere) by implementing a sensitivity analysis; 2) determine if the lake can support the expansion or addition of a fish farm; 3) provide practical information to regulators (e.g., to compliment the Decision Support Tool (DST)) and make sound science-based decisions for lake management.

Preliminary results show that feeder tributaries are the most sensitive parameter in terms of phosphorus loading to Lake Wolsey, followed by the inlet exchange rates with the open lake, and, finally, by the contributions of the farm itself. Information from this project will: 1) provide improved understanding of the relative phosphorus contributions of a fish farm to a freshwater lake in Ontario; and 2) assist water quality managers by supplying scientific information to aid in the decision-making processes related to determining policy and regulatory approaches to sustainable aquaculture management in Ontario.

Jan. 2008 – Dec. 2011 • Funded by: Environment Canada
Project team: Richard D. Moccia (U of Guelph), Jacqui Milne (U of Guelph) • Contact: Richard D. Moccia (rmoccia@uoguelph.ca) • www.aps.uoguelph.ca/aquacentre

Evaluation of ecosystem-level effects of bivalve aquaculture activities: mussel culture in Gaspé

A regional priority in Québec is to better understand the functional relationship between increased organic sedimentation due to suspended bivalve aquaculture and benthic responses to better predict the benthic ecological carrying capacity of sites for suspended bivalve aquaculture. This project constituted a scoping study in Gaspé in the fall of 2008 to evaluate the impact of current aquaculture practices on the benthic environment. As a first step in a larger future research, this work was limited to infaunal and sediment samples to evaluate if patterns relating to mussel farming exist. Benthic samples were taken below and between mussel lines in each of 3 stations within mussel farms and at each of 3 reference stations. All organisms recovered were identified. Although sites differed from one another, there was no evidence of an influence of bivalve culture on benthic communities. It is suggested that this is due to the low density of mussel culture in the area and great natural organic enrichment from a near-by river. Directed manipulative studies would have to be undertaken to determine the level of loading that would modify benthic communities in this environment.

Apr. 2008 – Mar. 2009 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
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An icy start to a day in the field

Chris McKindsey (DFO)

Marc Skinner

Zostera flowering

Influence of Eastern Oyster aquaculture on eelgrass populations and their recovery

International and regional scientific consensus has been achieved on the critical ecological position of eelgrass (*Zostera marina*) in providing fish, bird and invertebrate habitat as well as nursery habitat for juvenile fauna. Eelgrass also plays an important role in enhancing nutrient cycling and sediment stabilization. Worldwide seagrass declines have been associated with anthropogenic stressors, especially those linked to decreased underwater light levels or reduced water clarity associated with increased nutrient and sediment loading. Recently, the project team has demonstrated localized reductions in eelgrass distribution, growth rate and photosynthetic capacity linked to shading from oyster culture equipment used in the southern Gulf of St. Lawrence.

Based on these observations, DFO Habitat Management and the regional oyster industry have requested advice regarding the temporal and spatial recovery patterns of eelgrass in areas exposed to suspended bag, as well as off-bottom (i.e., table) culture. This project is designed to gain a better understanding of eelgrass recovery processes, while developing best management practices to guide industry in mitigating any effects. Multi-year field experiments examining the recovery dynamics of eelgrass exposed to both culture methods are underway, with additional experiments on lease fallowing strategies planned for the coming field season.

Apr. 2010 – Mar. 2013 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), L'Étang Ruisseau Bar Ltd.
Project team: Marie-Hélène Thériault (DFO), Simon Courtenay (DFO/Canadian Rivers Institute), Marc Skinner (DFO/Canadian Rivers Institute), André Mallet (L'Étang Ruisseau Bar Ltd.), Claire Carver (L'Étang Ruisseau Bar Ltd.)
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Dose-dependent relationships for biodeposition from farmed mussels and benthic responses

One of the most evident impacts of bivalve culture is its influence on the seabed and the development of a sustainable aquaculture industry requires the ability to predict such impacts. Several knowledge gaps need addressing to develop predictive models to this end. These include: valid estimates of biodeposit production by cultured species, the functional response of benthic communities to increasing organic enrichment due to biodeposition from cultured bivalves, and the development of appropriate indicators of benthic community condition. We are addressing some of these gaps by using modeling approaches to estimate biodeposit production and its influence on the seabed, evaluate predictions through a series of *in situ* experiments, and parameterize an index of benthic condition for Eastern Canada conditions. Preliminary results from large *in situ* mesocosm studies done in the Magdalen islands in 2010 show that sediment biogeochemical parameters and oxygen concentration change predictably with increasing organic loading from mussel biodeposition. Analysis of biological communities is on-going. Proposed work in 2011 will repeat and expand upon this work in Prince Edward Island, provide realistic estimates of biodeposit production, and develop a model to predict benthic condition for different culture scenarios.

Apr. 2010 – Mar. 2013 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
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Development of off-shore aquaculture in the southern Gulf of St. Lawrence: bottom mapping

A Wide Angle Seafloor Sonar Profiler (WASSP) (multi-beam) and the OLEX sea mapping software has been installed aboard the Opilio, the Gulf Region research vessel. During every research mission since the installation, marine bottom information is being gathered simultaneously as various project leaders conduct their research aboard the Opilio. The real-time 3D seafloor profiler is providing bathymetric contour mapping. A good understanding of the physical characteristics of the seabed is a key element in habitat characterization.

In the Gulf Region, the lobster group has a WASSP and OLEX system on their inshore vessel. At the end of November, after the Opilio has completed the 2009 missions, the bottom mapping data acquired on the Opilo will be downloaded and combined with the near-shore data obtained using the lobster group's inshore vessel. Presently, it is planned to download the data at the end of each year to create yearly marine bottom maps. Every time the Opilio sails, the contour maps are up-dated, therefore yearly maps will provide a means to document the changes as they occur. Users will be able to compare the marine bottom maps from one year to the next.

Apr. 2008 – Mar. 2009 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
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Tracking aquaculture's interactions with wild species

A multi-year investigation was designed to determine if the natural carotenoid pigments – astaxanthin and canthaxanthin – that are added to salmon feed for nutritional and pigmentation purposes can be found in wild species living near salmon cage sites. These pigments give wild and farmed salmon flesh its red or pink colour, and are important for proper growth and development. Wild salmon obtain this pigment through their natural food, such as krill and other crustaceans. Consumption of dispersed aquaculture feed could result in higher concentrations of these pigments being found in species living close to cage sites. Therefore, samples of local invertebrates (American Lobster, scallops, sea urchins, Rock Crabs, Horse Mussels, and the common Northern Sea Star) were taken from three adjacent sites (less than 100 m) to salmon cages and three sites four to six kilometres distant from the nearest cages. These wild species were chosen for their abundance, long residence time, ease of capture, and commercial value. Initial results show that canthaxanthin can be detected in the reproductive and digestive tissues of several species (crab, lobster, sea urchins). In most invertebrate samples from locations closest to the cage sites canthaxanthin was detected at concentrations ranging from 2.5 to 7.9 ppm. However, this pigment was not detected in the same species collected four to six kilometres away from these aquaculture sites. The pigment astaxanthin, by contrast, was found at low levels in all samples both near and far from the salmon cage sites. But, since it is available from natural sources in the environment, its presence does not necessarily indicate exposure to aquaculture feeds. While these pigments have not been shown to do any harm to the wild species sampled, the study of canthaxanthin's distribution through the ecosystem may provide a valuable tool to objectively evaluate how aquaculture activities interact with the environment and to further understand nutrient flow within and around cage sites.

Oct. 2006 – Mar. 2009 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
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Characterizing the zone of influence downstream of longline mussel leases

Cultivated bivalves can deplete available food resources faster than the ecosystem can replace them through primary production and tidal currents. In contrast to other parts of the world, there are no minimum partition requirements between mussel leases in PEI, and little is actually known about the zone of influence downstream of leases. This project proposes to characterize food particle depletion within this zone of influence and investigate to what extent the layout of mussel crops can modulate this zone. Predicting the zone of influence is relevant to the siting of new leases and to the development of bay management plans. We found localized depletions in food particles, from 5 to 3 µg chlorophyll-a L^{-1}, in areas where current velocities are low (< 10 cm s^{-1}). However, the depletions rarely extended beyond lease boundary, an outcome that provides little support to the implementation of a partition between mussel leases.

2009 - 2010 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
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Harbour Porpoise presence patterns at an aquaculture cage site in the Bay of Fundy

Finfish aquaculture is a prominent industry in the Bay of Fundy, Canada. The distribution of Harbour Porpoise (*Phocoena phocoena*) in the bay during the summer and fall may be impacted by the presence of offshore cages and the activities of workers on the site. Harbour Porpoise presence near and within an aquaculture cage site was studied using visual observations during the summer of 2006 and by monitoring echolocation signals using T-PODs during the summer and autumn of 2006 and 2007. At least one Harbour Porpoise was sighted per hour 61% of the time among or near the cages. Porpoises occasionally surfaced within the cage site when workers were present. Mother-calf pairs used the within-cages area proportionately more than adults and juveniles. The porpoises were temporarily displaced by the high disturbance activities such as cage cleaning with pressure hoses, but quickly returned to the area when the disturbance ended. Echolocation activity was lowest during the day, increased in the evening, and peaked between midnight and dawn. This pattern was evident on the offshore and onshore side of the cages and, to a lesser extent, at a non-aquaculture location farther along the coastline (2007 only). In August of both years, the echolocation patterns were similar, even though in 2007 there were no fish in the cages and much less worker activity than in 2006 when all 15 cages contained Atlantic Salmon (*Salmo salar*). Echolocation activity near a T-POD typically lasted for no more than 10 min or for at least 1 h, suggesting that the porpoises were either passing by the area or staying to feed, respectively. The presence of the aquaculture cage site under study did not appear to be displacing Harbour Porpoise from the area except during short intervals when high disturbance activities such as a food delivery by barge or cage cleaning were occurring.

Jan. 2009 – Dec. 2009 • Funded by: Fisheries and Oceans Canada (Species at Risk Program), Natural Sciences and Engineering Research Council
Project team: M.L. Haar (UNB), L.D. Charlton (UNB), J.M. Terhune (UNB), Ed Trippel (DFO – SABS)
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Harbour porpoise DFO

Carpe Diem Consulting

Jon Foxley River Fishers 2010

Development of aquaculture management plans for PEI aquaculture areas

The current expansion of oyster aquaculture on PEI requires an increase in the off-bottom lease acreage. This trend within the industry is facilitated by the conversion of existing bottom culture leases to off-bottom and is supported by joint federal/provincial/industry funding programs such as the Strategic Oyster Aquaculture Renewal (SOAR) Program. This conversion process is governed by the PEI Lease Management Board, which has stated that certain areas require Aquaculture Management Plans to be in place before any further lease conversions can be considered.

A series of consultations with leaseholders, local watershed management groups, First Nation organisations and wild fishery associations were held to identify the opportunities and challenges for further aquaculture development in this area. Federal and Provincial government stakeholders, such as Transport Canada, Fisheries and Oceans Canada and the PEI Department of Fisheries, Aquaculture and Rural Development for example, were also consulted.

The result of these consultations is a strong, industry-led Aquaculture Management Plan for the Foxley/Trout River system that clearly demonstrates the commitment of local shellfish aquaculturists to environmental sustainability in their farm management practices and will facilitate the continued expansion of oyster aquaculture.

Apr. 2010 – Mar. 2011 • Funded by: PEI Atlantic Shrimp Corp., Fisheries and Oceans Canada (DFO), PEI Department of Fisheries, Aquaculture and Rural Development
Project team: Peter Warris (R&D, PEI Aquaculture Alliance), Crystal MacDonald (Carpe Diem Consulting) • Contact: Peter Warris (rd@aquaculture.pei.com)
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Development of phytoplankton depletion criteria for assessing mussel culture carrying capacity

Given the high intensity of suspended mussel culture in some areas and the potential for interactions with other users of coastal waters, an ecosystem-based perspective is needed to ensure that aquaculture is carried out in a sustainable manner. The spatial extent and magnitude of seston and phytoplankton depletion associated with different husbandry practices and oceanographic settings are being studied through a broad international collaboration. The objectives of this work are to:

1) develop a reliable method for rapidly mapping the spatial scale of phytoplankton depletion within and outside suspended mussel farms;
2) obtain field data (depletion maps, water flow and mussel stocking) from a wide range of geographic and aquaculture settings (long-line, raft, and bottom culture grow-out and spat collectors) to develop a statistical model for predicting phytoplankton depletion; and
3) identify critical phytoplankton depletion limits (thresholds) for assessing the ecological carrying capacity of suspended mussel farms.

Data from this project are also contributing to the development and testing of mussel farm-scale and ecosystem models in several countries and can be used for optimizing mussel production at the coastal ecosystem-scale.

Apr. 2008 – Mar. 2013 • Funded by: Fisheries and Oceans Canada (DFO), Danish Council for Strategic Research, Research Council of Norway, Netherlands Ministry of Agriculture, Nature and Food Quality, Spanish Ministry of Science and Innovation
Project team: Peter Cranford (DFO), Øivind Strand and Tore Strohmeier (Norwegian Institute of Marine Research), Pauline Kamermans and Karin Troost (Netherlands Institute for Fisheries Research, Wageningen University and Research Centre), Maria José Fernández-Reiriz and Uxio Labarta (Instituto de Investigaciones Marinas), Pedro Duarte (Universidade Fernando Pessoa), Jens Petersen (The Danish Shellfish Centre), Proinsa mussel farms (Spain)
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Tracking the resuspension and transport dynamics of aquaculture wastes and their associated sediments for predictive model development and refinement

Scientific understanding of the far-field impacts of aquaculture is limited, especially with regard to the resuspension and transport of aquaculture wastes. A monster *IN situ* Size and SEttling Column Tripod (m-INSSECT) was deployed for one month in Bliss Harbour, NB, starting on August 16th, 2010. The tripod was instrumented with a LISST 100x type C, a digital floc camera (DFC), an *in-situ* settling column (DVC), a Nortek aquadopp, a McLane water transfer system (WTS), and a conductivity, temperature, and depth (CTD) sensor. The LISST 100x and DFC measure particle sizes from 2 µm to several mm, while the DVC is used to determine particle size versus settling velocity relationships. The aquadopp in its tripod configuration measured both the shear stress exerted on the seabed from waves and currents and backscatter, which can be used as a proxy to determine the change in suspended sediment concentration. The WTS filters 24 water samples *in-situ* and gives detail on the suspended mass concentration during each sampling interval. Finally, the CTD measured the salinity and temperature of the water. In addition, bottom sediment cores were collected and coupled to a GUST erosion device to determine the mass of material eroded, particle size, and trace metal and organic carbon concentration under differing stress conditions. Evaluation of the data will serve to refine or develop aquaculture waste transport models.

2010 • Funded by: DFO, OAS
Project team: Brent Law (DFO), Tim Milligan (DFO), Gary Bugden (DFO), Vanessa Page (DFO), Tina Lum (DFO), Fred Page (DFO), Randy Losier (DFO)
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Jon Grant (Dalhousie University)

Mussel aquaculture in Lysefjord, southern Norway

Carrying capacity in Norwegian aquaculture (CANO)

Norway has many fjords suitable for shellfish culture, but they are highly stratified, with deep nutrients and low summer production. Pilot studies have shown that inducing local upwelling of nutrients by pumping freshwater to depth stimulates phytoplankton production, creating improved food conditions for cultured mussels. Field, laboratory, and modeling studies were conducted in a Norwegian fjord by international participants in order to quantify the potential of this approach. We conducted several modeling studies to examine the density and location of mussel farms to take advantage of enhanced phytoplankton production. This project allowed development of a fully spatial model for ecosystem-based management of aquaculture. This model has already been applied to several sites in eastern Canadian waters.

2007 - 2010 • Funded by: Institute of Marine Research
Project team: Jon Grant (Dalhousie University), Øivind Strand (IMR Bergen)
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Management of husbandry practices to maintain water column environmental carrying capacity for bivalve culture

Bivalves are filter-feeding organisms that extract suspended food particles from the water column with an extraordinary filtration capacity. Densely stocked bivalves can deplete available seston faster than the ecosystem can replace it through primary production and water renewal. Both industry and regulatory agencies recognize a need to identify the stocking density at which the demand for food particles is well matched to the supply. Internationally, laudable research efforts are being made to develop simple standards and elaborate numerical models, with a common goal of assessing whether farming operations have exceeded the environmental carrying capacity of a system. However, knowledge gaps are becoming apparent, such as the influence of husbandry practices on the time it takes a population of cultivated bivalves to filter a body of water. Our broad objective is to further the development of carrying capacity indicators for longline mussel farming areas. Specifically, we will integrate the husbandry factor as a forceful variable in model simulations and predictions, with the end objective of developing a decision support tool that is state-of-the-art as far as aquaculture planning goes.

2010 – 2012 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
Project team: Luc Comeau (DFO – GFC), Jon Grant (Dalhousie University)
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www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp

Ecosystem modeling of sustainable aquaculture

Although sustainable aquaculture is an important management goal, the definition and measure of sustainability has been elusive. Ecosystem modeling has become a well-developed approach in prediction of culture production, and has progressed into operational models in many countries. These models consist of circulation models coupled to biogeochemical models which include shellfish feeding and growth. We have produced these models for several bays in eastern Canada, including measures of sustainability based on chlorophyll depletion by suspension-feeding shellfish. The focus of sustainability is preservation of coastal ecosystem function and integrity. Most recently, the work has an increasing context of integration into coastal zone management and GIS.

Jan. 2009 – Nov. 10 • Funded by: NSERC
Project team: Jon Grant (Dalhousie University), Ramon Filgueira (Dalhousie University)
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Peter Cranford (DFO)

Two DFO coastal vessels from BIO being prepared to conduct the survey work

Mussel aquaculture regulatory effectiveness monitoring: validation of the environmental assessment and monitoring program in St. Ann's Harbour

The largest single mussel aquaculture application in the Maritimes was approved in 2003 for St. Ann's Harbour, Nova Scotia after an assessment of environmental risks and the implementation of a rigorous environmental monitoring program (EMP). The mussel leases in St. Ann's Harbour are approximately 70% developed and an intensive environmental sampling program was conducted to test both the impact assessment predictions and the effectiveness of the EMP design. Existing site monitoring data and pre-development data were also utilized in a retrospective analysis of aquaculture/ecosystem interactions. Data collected during this study were used to provide advice on how shellfish aquaculture monitoring programs may be made more spatially and statistically meaningful using the same sampling effort as currently used in the site EMP (e.g., number of seabed samples collected). A technical report containing project results and conclusions is currently in press by the project team, which included representatives from DFO Science, DFO Habitat Protection and Sustainable Development Division, Dalhousie University, the Nova Scotia Department of Fisheries and Aquaculture, and industry. The recommendations contained in this report are provided to increase the scientific certainty of monitoring results while permitting the mussel aquaculture industry to remain economically viable.

Apr. 2009 – Mar. 2011 • Funded by: DFO – Program for Aquaculture Regulatory Research (PARR)
Project team: Peter Cranford (DFO – BIO), Joe Crocker (DFO – BIO)
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Mussel culture carrying capacity in St. Ann's Bay

St. Ann's Bay is an ideal site for longline mussel culture with productive Gulf waters and low rural population density. Parts of the bay have been cultured, and ongoing monitoring by DFO and Nova Scotia Department of Fisheries and Aquaculture has been used to assess benthic health. As with many mussel culture sites, there are minimal benthic impacts. We sought to use an ecosystem approach to culture carrying capacity via ecosystem modeling to assess the degree of chlorophyll depletion due to suspension-feeding mussels. Studies of the bay are not often seasonal, and a time series of water quality is important in initializing the model. In order to make models of carrying capacity more operational, we used satellite remote sensing to define seasonal changes in chlorophyll in the nearshore. By simulating chlorophyll levels in the presence and absence of mussels, we were able to define culture levels that did not severely impact water quality, maintaining the integrity of the ecosystem for other consumers.

2009 – 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Nova Scotia DFA, Enterprise Cape Breton Corporation
Project team: Robin Stuart (Englishtown), Jon Grant (Dalhousie University), Ramon Filgueira (Dalhousie University) • Contact: Jon Grant (jon.grant@dal.ca)

Indicators of coastal ecosystem health

There is much interest in indices of ecosystem state or health, and many of these incorporate measures of biodiversity. A lot of the focus revolves around aquaculture impacts, and there is a need to describe the health of the far-field, i.e., beyond the limits of the cultured areas. Although describing system state following perceived impacts is useful, it would be more valuable to make predictions of system health in advance of activities such as aquaculture development. In this project, we sampled benthic biodiversity in several bays, and examined sediment characteristics as predictive variables. A critical difference from previous studies was controlling for spatial sample location in the regression model. This allowed for a reduction in the number of samples, and changed the relative influence of sediment variables as predictors. The technique has many implications for sample design as well as approaches to predictive power in system-wide studies. Moreover, we were able to conduct some of the research in collaboration with coastal communities as stakeholders in the data collection and decision process.

2008 - 2011 • Funded by: NSERC Strategic Project Grant
Project team: Jon Grant (Dalhousie University), Mike Dowd (Dalhousie University)
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An investigation of reproduction between wild and farmed salmon in Newfoundland

Since the late 1970s, salmon aquaculture has grown into a global industry, producing over 1 million tonnes of salmon per year. The majority of this biomass is held in open net pens in coastal areas, areas through which Atlantic Salmon migrate on their way to and from the ocean. Atlantic Salmon abundance has been declining for several decades, preceding the arrival of intensive salmon aquaculture in Newfoundland's coastal waters. It is very difficult to assess the effects salmon farming has had on the highly dynamic, migratory wild salmon populations, due to other environmental and anthropogenic variables such as oceanographic and climate conditions, habitat loss, and human interactions in coastal areas.

The finding that the effects of salmon farming on wild salmon do not increase linearly with the tonnage of farmed salmon highlights the need for a better scientific understanding of the situation. In Newfoundland, the introduction of farmed salmon originally from the Saint John River strain to the Bay d'Espoir area raises the question of potential effect of escapes on wild stocks. With the support of the aquaculture partner (Gray Aqua Group) and the Council of the Conne River Micmacs (Miawpukek Mi'kamawey Mawi'omi), this project aims to answer the question of mating success between farmed mature fish and wild spawners from Newfoundland river stocks. Fertilization rates and gamete quality will be assessed in both farmed and wild mature fish and crosses will be completed to evaluate fertilization and hatch rates. The effect of the water quality (river waters) will be tested to better understand the potential reproductive effect of salmon escapes from local farms on wild spawners in their natural environment.

Apr. 2010 – Apr. 2012 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Gray Aqua Group
Project team: Dounia Hamoutene (DFO), Danny Ings (DFO), Gehan Mabrouk (DFO), Lynn Lush (DFO), Kimberley Hobbs (DFO), Clyde Collier (Gray Aqua Group Ltd.), Brian Dempson (DFO), Ian Fleming (Memorial University), Ross Hinks (Miawpukek Mi'kamawey Mawi'omi)
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Altantic Salmon collection Dounia Hamoutene (DFO)

Finfish aquaculture site development: fate of fish waste

New finfish aquaculture sites being developed in Newfoundland are often located over deep waters (> 100 m) with hard bottom substrates that are difficult to monitor for regulatory purposes. One of the primary aims of monitoring at finfish sites is to determine the potential influences of organic input on benthic habitats. To investigate the fate of wastes associated with fish farming and the potential influences on benthic communities at sites on the south coast of Newfoundland, we initiated a study to validate DEPOMOD. This model was developed by the Scottish Association for Marine Science and it predicts the dispersion of particles from cage sites. Site specific current data, bathymetry, cage orientation, feeding regime and feed properties are all input into model runs. Data used to validate DEPOMOD were collected during two periods: late July to late August and late August to mid-October of 2010. We sampled using sediment traps to estimate organic input along transects extending from an Atlantic Salmon farm and a Rainbow Trout farm. Additionally, we collected video data along transects on both sides of the sediment traps to determine the benthic community response to organic input. The model predictions will be compared to the observed organic flux. Also, video data of the benthos will be analyzed and compared to the data on organic flux around cages.

May 2010 – Mar. 2013 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Cold Ocean Salmon Inc., Northern Harvest Sea Farms
Project team: Danny W. Ings (DFO), Gehan Mabrouk (DFO), Fred Page (DFO), Dwight Drover (DFO), Dounia Hamoutene (DFO), Randy Losier (DFO), Sharon Kenny (DFO), Terry Bungay (DFO) • Contact: Danny Ings (danny.ings@dfo-mpo.gc.ca)
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Oceanographic study of the south coast of NL

The province of Newfoundland is experiencing a significant influx of investment in salmonid farming. Since 2004, 50 new marine sites for Atlantic Salmon and 6 new sites for Steelhead Trout have been licensed in the Bay d'Espoir-Fortune Bay area. An additional 17 sites were under review in 2008. The increasing biomass, the increase in the number of companies operating, the diversity of production strategies, and the increasing concentration of farm sites, particularly in outer Bay d'Espoir, challenges biosecurity and the sustainability of this growth. Currently there is a lack of data and understanding of the oceanography of the outer Bay d'Espoir area that precludes establishment of scientifically validated production and management areas to guide site licensing, production planning and sustainable management of the industry. The project will establish the infrastructure and the foundation for Newfoundland to be able to carry out an oceanography program to collect and model the physical environmental data - currents, dissolved oxygen, temperature, and salinity - and map the environmental parameters and potential zones of influence that will be used to establish production management areas. A great deal of oceanographic data has been collected to date and its analysis is ongoing. The results of the drifter program, a component of the whole oceanography work, were presented in a DFO CSAS workshop on Nov. 2010.

Apr. 2008 – Mar. 2013 • Funded by: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)
Project team: Gehan Mabrouk (DFO), Fred Page (DFO – SABS), Dwight Drover (DFO), Randy Losier (DFO – SABS), Paul McCurdy (DFO – SABS), Mike Foreman (DFO), Dave Senciall (DFO) • Contact: Gehan Mabrouk (Gehan.mabrouk@dfo-mpo.gc.ca)
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The Aquamax Net Manager in the water

Deane Larson

Aquamax Net Manager: green net management

Fish pen nets that hang in the ocean can become covered with algae, crustaceans, tunicates, etc. which impede the flow of water and oxygen in and out of the net pens. The build-up on the nets is referred to as "biofouling". Not only can biofouling be unhealthy for the fish, but it can also increase the weight of the net. Biofouling poses a continuing challenge to aquaculture producers in British Columbia. Existing management techniques, such as copper-based anti-fouling dips, pose potential environmental and fish health concerns, are of limited effectiveness, and may reduce net durability.

Shorelink Enterprises has addressed these concerns with the development of an innovative, environmentally-friendly, efficient, economically-viable, and modular anti-fouling technology. The Aquamax Net Manager is a transportable net cleaning-system that is moved by vessel or barge from aquaculture site to the aquaculture site. The system does not require that the cage nets be removed from the water for cleaning. It can also be moved over land using its own customized transport trailer or partially disassembled for easy placement in shipping containers for long-distance travel.

On-site testing of the Aquamax Net Manager has demonstrated efficient, effective net cleaning capability. In addition to its environmental benefits, this new technology offers significant cost saving potential through reductions in the need for existing anti-fouling agents, net inspections conducted by divers, traditional net cleaning and through increases in net longevity.

July 2009 – Aug. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program (AIMAP), Shorelink Enterprises Ltd., Sablefish Canada Inc.
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Key viral characteristics for infectious hematopoietic necrosis virus (IHNV) in Atlantic Salmon

In British Columbia, IHNV is the most economically important viral pathogen of salmonids. Since the introduction of Atlantic Salmon to the BC coast in the mid 1980s, there have been two disease outbreaks of IHN in farmed Atlantic Salmon resulting in an estimated $200 million in lost sales.

A central question regarding these outbreaks is the role of natural waterborne transmission in the spread of virus between farms and to surrounding wild salmonid populations. The IHN virus can survive for several hours in saltwater at temperatures below 15°C. Therefore, it's not unconceivable that viable and infective IHNV could be transmitted by movement of water from virus infected Atlantic Salmon farms to uninfected fish either proximal or distant from the source.

Water circulation models can be used in developing pathogen dispersal models and in assessing transmission risks. Key properties required in the development of a viral dispersal model are the relationship between the rate of viral shedding, the viral concentration in sea water and the minimum dose of virus required to induce infection in Atlantic Salmon. At the DFO Pacific Biological Station, quantitative estimates of these parameters have been determined for Atlantic Salmon post-smolts. This information is being incorporated in a water circulation model being developed at the DFO Institute of Ocean Sciences, to provide more accurate geospatial predictions of risk for IHNV in farmed Atlantic Salmon.

July 2009 – Mar. 2011 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Grieg Seafood, Mainstream Canada, Marine Harvest Canada
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Okisollo

Darren Tuele

Kudoa thyrsites – increasing our knowledge

BC CAHS

Plasmodia of *Kudoa thyrsites* within the muscle

Kudoa thyrsites is an intramuscular parasite that has a world wide distribution and can infect several species of fish. This parasite imposes no fish health risks, but instead affects product quality by causing pitting and softening of the fish muscle tissue after harvest. At low levels of infection the pathology of *Kudoa thyrsites* infection can go unnoticed, but at higher levels it produces extensive myoliquefaction and the fish meat is no longer commercially viable. Marine Harvest Canada and the BC Centre for Aquatic Health Sciences (BC CAHS) have embarked upon a 3 year joint research and development project to increase our understanding of *Kudoa thyrsites*. During the first year, two saltwater farm sites will be monitored to determine when the fish become infected and how the infection develops throughout the production cycle. In addition, this initiative will also aim at identifying the infective stage of the parasite and to develop a non-lethal test that allows for tracking individual fish throughout the production cycle. This increased knowledge of the parasite's life cycle and infective stages, timing and progression of infection may lead to effective management decisions to limit or avoid infection, future vaccine development, and improved husbandry strategies.

May 2010 – Apr. 2012 • Funded by: Marine Harvest Canada
Project team: Diane Morrison (Marine Harvest Canada), Luis O.B. Afonso (BC Centre for Aquatic Health Sciences), Tiffany MacWilliam (MHC), Wyth Marshall (BC-CAHS), Heather Lamson (BC-CAHS), Ena Richmond (BC-CAHS), Paula Galloway (BC-CAHS), Sonja Saksida (BC-CAHS)
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Identify and understand the virulence factors of *Aeromonas salmonicida*, the bacteria causing Furunculosis

Furunculosis is an infectious disease occurring particularly in farmed trout and salmon. The disease is caused by the *Aeromonas salmonicida* bacteria. Despite the available treatments (antibiotics, vaccination), Furunculosis is recurrent and causes serious problems for aquaculturists. One solution to this problem involves creating compounds to complement antibiotics and decrease the infectious nature of the bacteria. The development of these anti-infection agents requires, as a first step, better understanding the virulent behaviour of the bacteria and thus finding molecular targets suitable for developing these anti-infection agents. We are therefore studying the type-three secretion system (TTSS), an essential virulence factor of *A. salmonicida*. More specifically, our analysis examines the role of certain toxins secreted by the TTSS and the stability of the genes coding for this system. Concurrently with this research, an approach including genetic screening and genomic analysis will be implemented to identify new genes involved in the virulence of the bacterium. The objective is to define the infectious nature of *A. salmonicida* and propose new approaches for treating infections caused by this bacterium.

Mar. 2006 – ongoing • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), Réseau Aquaculture Québec (RAQ)
Project team: Steve Charette (Laval University), Stéphanie Dallaire-Dufresne (Laval University), Katherine Tanaka (Laval University), Geneviève Filion, Michael Reith (IBM-CNRC)
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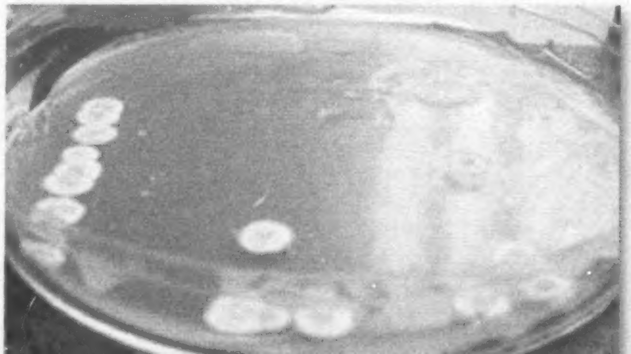
Strategies to prevent off-flavours in fish raised in closed-circuit aquaculture system

In recirculating aquaculture systems, the growth of certain bacteria (*Streptomyces*) can produce chemical compounds with an earthy odour. These compounds, primarily geosmin and 2-methylisoborneol (2-MIB), are semi-volatile and non-toxic and accumulate in fish tissue. Treatment of the odour/flavour causes delays in fish production and marketing, resulting in economic losses. Pure strains isolated at Laboratoire régional des sciences aquatiques (LARSA) (Université Laval) and identified as *Streptomyces lavendulae* and *S. aculeus* have been used to create specific molecular tools from synthetic genes (cyc/GeoA). These tools are designed to facilitate the detection, monitoring and quantification of these bacteria to warn aquaculturists of the presence of off-flavour-producing *Streptomyces* in aquaculture tanks. This project is also designed to identify the factors leading to the development of *Streptomyces*. The procurement and use of probiotic bacteria should create competition, thereby slowing the development of *Streptomyces* and the production of off-flavours, while improving water quality and fish health. Bacterial competition will be evaluated in the laboratory and in recirculating tanks. This project should make it possible to facilitate the development of recirculating aquaculture systems in Canada.

Apr. 2010 – Mar. 2012 • Funded by: Armand Frappier Institute (IAF-INRS, Université Laval, NSERC
Project team: Marc Auffret (IAF-INRS), Grant Vandenberg (U Laval), Alexandre Pilote (U Laval), Daniel Proulx (U Laval), Richard Villemur (U Laval), Janusz Pawliszyn (U Laval), Yves Comeau (U Laval) • Contact: Marc Auffret (Marc.Auffret@iaf.inrs.ca)


Marc Auffret (IAF-INRS)

Culture of a strain of *Streptomyces*

Prevention of off-flavours in fish grown in recirculating aquaculture systems

The presence of off-flavours in farm-raised fish represents one of the most significant economic problems encountered in aquaculture related to product quality and may cause a major reduction in the consumption of the products, or make them unsuitable for sale. Off-flavours are due to the absorption of substances, including geosmin and 2-methylisoborneol (MIB). When present in water these substances accumulate in the fat of fish.

The main objective of this project is to develop strategies to prevent the occurrence of geosmin and MIB in recirculating aquaculture system (RAS). The hypothesis is that it is possible to produce fish in RAS without off-flavours in the fish by selectively controlling the development of off-flavour producing microorganisms by: (i) manipulating key operational parameters of RAS, (ii) optimizing diets that reduce off-flavour producing compounds, and (iii) adding compounds that would selectively eliminate off-flavour-producing microorganisms that have no effect on wastewater treatment biofiltration, and the fish. This will be achieved by: (1) identifying and localizing microorganisms responsible; (2) developing a technique for real-time non-destructive detection of MIB and geosmin; (3) identifying the key environmental, nutritional and operational parameters involved in the development of these microorganisms; and (4) increasing the control on the microorganisms responsible for off-flavours.

Oct. 2009 – Oct. 2012 • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), Institut national de recherche scientifique (INRS), Interprovincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD/PIDDAED), Réseau Aquaculture Québec (RAQ), Société de Recherche et de Développement en Aquaculture Continentale (SORDAC Inc.)

Project team: Richard Villemur (INRS), Yves Comeau (Polytechnic school Montreal), Janusz Pawliszyn (University of Waterloo), Grant Vandenberg (U Laval), Marc Auffret (INRS-IAF), Karla Vazquez (INRS-IAF), Roger Dubuc (INRS-IAF), Alexandre Pilote (U Laval), Daniel Proulx (U Laval), Emilie Proulx (U Laval), Sanja Risticevic (University of Waterloo), Ziwei Bai (University of Waterloo), Kevin K. Schrader (US Dept Agriculture) • Contact: Richard Villemur (richard.villemur@iaf.inrs.ca)

BioCage to control fish farm escapes via a genetically modified food requirement

The ultimate objective of this study is to develop a line of transgenic Atlantic Salmon with an increased requirement for a specific nutrient that cannot be supplied by foods in the natural environment, but could be incorporated into fish feed formulations. Penned fish would remain healthy, but without the extra nutrient in their prepared feed; escaped fish would be unable to reproduce and would soon die due to lack of the missing nutrient.

The project is a three-year investigation designed to: 1) evaluate several genetic constructs that would have the effect of increasing the specific requirement for a particular nutrient; 2) use a model species to verify appropriate expression of the modified or introduced genes; and 3) validate the ability of special feed formulations to maintain good growth and health in the modified fish.

The requirements of non-transgenic fish for this nutrient have been assessed. An interaction between this nutrient and its natural antagonist in the diet of non-transgenic fish was studied. The genetic construct that increases the requirements for this nutrient was developed. The effect of this nutrient on fish reproduction must be verified before the production of the transgenic fish can be considered.

Oct. 2007 – Nov. 2010 • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), Atlantic Salmon Federation, Réseau Aquaculture Québec (RAQ-FQRNT), Laval University

Project team: Grant Vandenberg (U Laval), Marc Ekker (U Ottawa), Garth Fletcher (Memorial University), Lyne Létourneau (U Laval), François Pothier (U Laval), Rodrigue Yossa Nouaga (U Laval), Pallab-Kumar Sarker (U Laval), Fred Whoriskey (Dalhousie U), Bill Robertson (Atlantic Salmon Federation), Huntsman Marine Science Centre

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Biological approaches for the prevention and treatment of the fungus *Saprolegnia parasitica* in fish

Alevin infected by
Saprolegnia parasitica
Emilie Proulx (U Laval)

According to the Food and Agriculture Organization of the United Nations, epidemics are increasingly recognized as a major economic obstacle to aquaculture and trade in many countries around the world. Fungal diseases are the second leading cause of mortality in aquaculture, particularly in crustacean and finfish culture.

One of the most destructive pathogens is the fungus *Saprolegnia parasitica*. This fungus is widespread in most freshwater fish species and, if untreated, can cause mortality rates of up to 50% in a given population. New restrictions on the chemicals used to treat and prevent fungal infections have resulted in the need to find new alternatives. The objective of the project is to use beneficial microbial cultures or phytochemical products from the boreal forest to treat or prevent fungal infections. It will provide the fish farming industry with a new environmentally sound approach for preventing or controlling pathogens in order to ensure healthy products for Canadian consumers.

Apr. 2009 – Mar. 2012 • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), Société de recherche et de développement en aquaculture continentale (SORDAC) inc., Réseau Aquaculture Québec (RAQ)

Project team: Grant Vandenberg (U Laval), Pierre Belhumeur (U Montréal), Jean Legault (U Chicoutimi), André Pichette (U Chicoutimi), David Martel (U Laval), Jessica Seenevarsagachetty (U Laval), Vincent Domingue-Gauthier (U Montreal), Emilie Proulx (U Laval), Joe Schmidt (AgraQuest Inc.), Céline Audet (RAQ)

Contact: Grant Vandenberg (Grant.Vandenberg@fsaa.ulaval.ca)

Marketing transgenic fish and foods derived from cloned animals in Canada

The regulation of biotechnology developments is at the root of controversial moral issues. Some countries, such as the United Kingdom, Denmark and Norway, are "early adopters" and are quick to provide a framework for these developments. In other countries, considered "late adopters", there is a considerable time lag between the demonstration of technical and scientific developments and the adoption of appropriate normative frameworks. Canada is in the second group.

The purpose of this project is to explain the time lag in Canada through an analysis of the public policy development cycle in the area of the marketing of transgenic fish and products derived from cloned animals. We advance the hypothesis that the lag could be related to the presence of constraining factors or obstacles resulting from the interaction among ideas, political players and the political/administrative authorities responsible for adopting such policies. Specifically, we will examine the fact that the political/administrative authorities have more experience resolving technical issues than with resolving ethical issues, which reflects the values of the conflicting parties.

Jan. 2009 – Dec. 2013 • Funded by: Natural Sciences and Engineering Research Council of Canada (NSERC), Social Sciences and Humanities Research Council (SSHRC), Réseau Aquaculture Québec (RAQ), Réseau EmbryoGENE
Project team: Lyne Létourneau (U Laval), Olga Carolina Cárdenas-Gómez (U Laval), Louis-Simon Corriveau (U Laval), Steve Jacob (U Laval), Marc-André Sirard (U Laval), Grant Vandenberg (U Laval) • Contact: Lyne Létourneau (Lyne.Letourneau@fsaa.ulaval.ca)

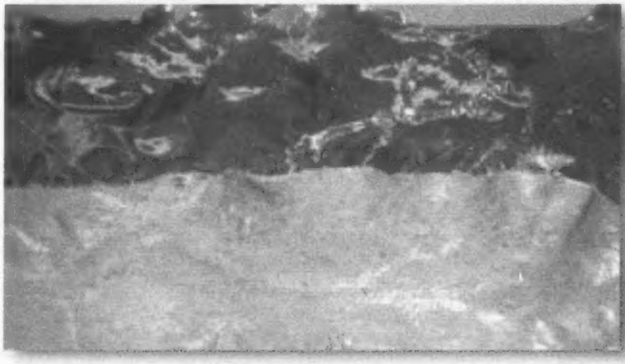
A new centre for seaweed research in Quebec

A centre for seaweed research, aquaculture and development (CEVAM, Centre d'Étude et de Valorisation des Algues Marines) has recently been created in Québec. Based at the École des Pêches et de l'Aquaculture du Québec (EPAQ), a fisheries and aquaculture technical school, CEVAM is a provincially-funded partnership between Université Laval in Québec City and the CEGEP de la Gaspésie et les Îles, the regional college in Gaspé. The goals of CEVAM are to promote both fundamental and applied research on macroalgae in the Gulf of St. Lawrence and the Canadian Arctic and to assess the potential for the exploitation of algal resources in natural and aquaculture settings. Training workshops on seaweeds are regularly organised. Research on natural seaweed populations is focusing initially on the ecology of kelp beds in cold water, looking more specifically at local and regional productivity and trophic interactions within these ecosystems. Current aquaculture projects involve three species (*Saccharina longicruris*, *Alaria esculenta*, and *Palmaria palmata*) that are cultured in the laboratory and then transferred to an offshore experimental farm to assess growth and harvest yields. CEVAM research will generate key ecological data for the management of natural algal populations and the development of the algoculture industry in Quebec.

Mar. 2009 – ongoing • Funded by: MELS, Laval University
Cégep de la Gaspésie et des Îles, Société de développement de l'industrie maricole (SODIM), MAPAQ, DFO, FQRNT, NSERC • Project team: Éric Tamigneaux (CEVAM, EPAQ), Anissa Merzouk (CEVAM, U. Laval), Vivianne Bélair (U. Laval, GRIQ), Daniel Bourdages (CEVAM, EPAQ), Robert Chabot (UQAR), Mathieu Cusson (UQAC), Antoine Dumais-Roy (CEVAM, EPAQ), Louise Gendron (DFO – IML), Marie-Joëlle Leblanc (MERINOV), Aurélie Licois (MERINOV), Bruno Myrand (MERINOV), Laurent Seychelles (CEVAM, EPAQ) • Contact: Éric Tamigneaux (Etamigneaux@cgaspesie.qc.ca)
www.cevam.qc.ca

Training L. Seychelles (U Laval)

Brown Alga cultivation in the Gaspé Peninsula to avoid colonization by the bryozoan and to increase the number of annual harvests

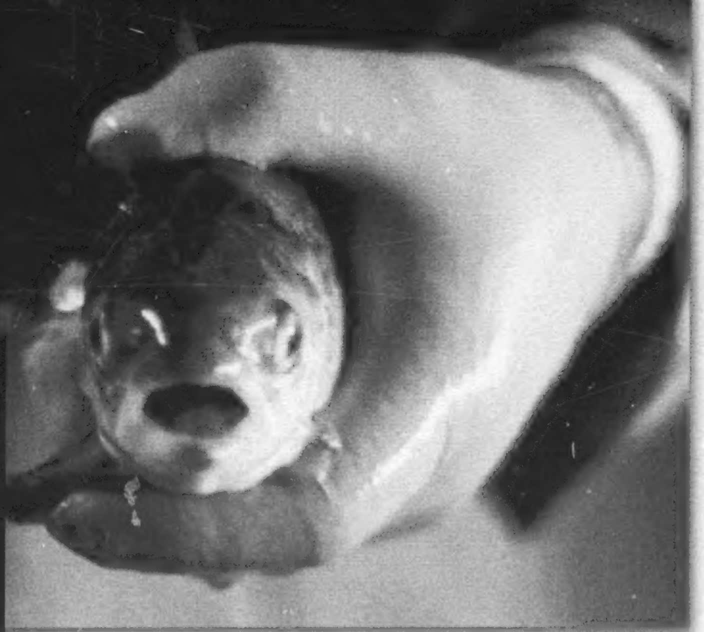


Louise Gendron (DFO)

Appearance of kelp blade covered with the bryozoan *Membranipora membranacea* (bottom) compared to a healthy kelp blade (top) (2006)

The Brown Alga (*Saccharina longicruris*) cultivation trials conducted in Chaleur Bay, Quebec in 2006 and 2007 involved a single annual production cycle (i.e., from April to November). During these trials, the plants were seriously degraded due to colonization by an invasive bryozoan (*Membranipora membranacea*) in summer. The objectives of the study conducted in 2008-2009 were to determine whether it was possible to reduce losses due to the bryozoan by altering the production cycle in order to avoid cultivating *S. longicruris* in summer and to obtain good yields with three four-month production cycles per year (fall, winter and spring cycles). The results show that short cycles do not allow for a sufficient yield. However, placing plants in the water in late fall and harvesting them the following July (8-10 month production cycle) could be an effective cultivation strategy for *S. longicruris*, with yields of 3.3 kg m^{-1} of line, comprised of large (blade ≥ 1 m), attractive blades, free of bryozoans.

Apr. 2008 – Jul. 2009 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Société de développement maricole (SODIM), Halieutec, DFO, Les Gaspésiennes inc.
Project team: Louise Gendron (DFO – IML), Éric Tamigneaux (Halieutec), Raymond Ferembach (Les Gaspésiennes inc.)
Contact: Louise Gendron (Louise.Gendron@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm



Atlantic Salmon being sampled for the vaccine study

Nellie Gagné (DFO)

DNA vaccine models against infectious salmon anemia virus (ISAV)

Infectious salmon anemia virus (ISAV) is a pathogen of salmonids and causes mass mortalities in aquaculture. It remains a recurrent problem in Eastern Canada and Maine since the initial epizootics of 1996.

DNA vaccines rely on the delivery and uptake of DNA plasmids in cells, and translation of an immunogenic peptide using the host machinery. Successful DNA vaccines have been produced against aquatic rhabdovirus, but DNA vaccines against ISAV are still not performing as expected.

Cross presentation is crucial for the generation of CD8 T cell responses against protein-based antigens. As the physiological capacity of antigen presenting cells to cross-present antigen is generally low, there is significant interest to develop reagents that enhance the targeting of exogenous antigens to the cross-presentation pathway.

Heat shock proteins (HSP) have numerous functions, including facilitating translocation of nascent chains across membranes, and targeting proteins for degradation within lysosomes. Studies have shown the efficient binding of small hydrophobic peptide sequences to HSP. Such binding sequences may be incorporated into a plasmid construct, to maximize the covalent binding of HSP with the antigen of interest.

We propose a novel approach using a plasmid construct expressing ISAV protein subunits combined to an HSP binding sequence, with a suitable linker and signal sequence.

Apr. 2009 – Mar. 2013 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Novartis Animal Health Canada Ltd.
Project team: Nellie Gagné (DFO), Mathieu Doucet (DFO), Mélanie Roy (DFO), Mark Laflamme (DFO), Kira Salonius (Novartis Animal Health Canada Ltd.), Nathalie Simard (DFO), Sybil Smith (Novartis Animal Health Canada Ltd.)
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Development of ELISA assays for detection of antibodies against viral pathogens in fish

Occasionally, viral pathogens that have short infection periods can be difficult to detect using diagnostic assays (e.g., viral culture or PCR). Seroconversion, the development of antibodies against a specific pathogen, is a typical response in many fish surviving systemic exposure to an infectious organism. Enzyme-linked immunosorbent assays (ELISA) are commonly used to assess the presence and titer of antibodies to viral pathogens (i.e., infectious salmon anemia (ISAV), viral hemorrhagic septicaemia (VHSV)), and are important tools in epidemiology and disease management strategies in farmed fish. Furthermore, samples can be collected using non-lethal sampling methods, an advantage when testing the health status of broodstock and valuable fish. These assays can provide important pieces of historical information such as whether a population has been exposed to the virus and whether a carrier state has been established in that population, thus guiding decisions regarding transfer (including import/export) or use of fish that may be asymptomatic carriers.

In this project, we will evaluate the current state of development of ELISA assays for the detection of antibodies against viral pathogens, including ISAV and VHS. An ELISA system will be developed and analytical validation of the assay should be performed minimally to determine the sensitivity and usefulness of the assay.

Apr. 2010 – Mar. 2013 • Funded by: DFO – CAAHRD (Centre for Aquatic Animal Health Research and Diagnostics)
Project team: Nellie Gagné (DFO), Mathieu Doucet (DFO), Mélanie Roy (DFO), Mark Laflamme (DFO)
Contact: Nellie Gagné (Nellie.Gagne@dfo-mpo.gc.ca)

Mélanie Roy, biologist, preparing cells for transfection

Mark Laflamme (DFO)

Fish physiology and nutrition

Valorization and commercialization of marine by-products for human and animal feeding and the applications in the prevention of obesity, diabetes and neurodegenerescence

The aim of this project is to identify and incorporate novel ingredients from marine by-products for Atlantic Salmon aquaculture feed.

Nine ingredients will be tested, but only three will be selected for larger scale studies, based on results from Objectives 1 and 2 (see below).

Objective 1: Determination of global gene expression patterns following stimulation by novel fish feed formulations. Initially, global gene expression patterns will be compared over time following stimulation by a series of novel fish feed formulations. This initial study will help us determine which formulations have the most potential at the genetic level. Only formulations showing the most interesting genetic responses will be further studied at the physiological level. The genetic and physiological responses will then be correlated.

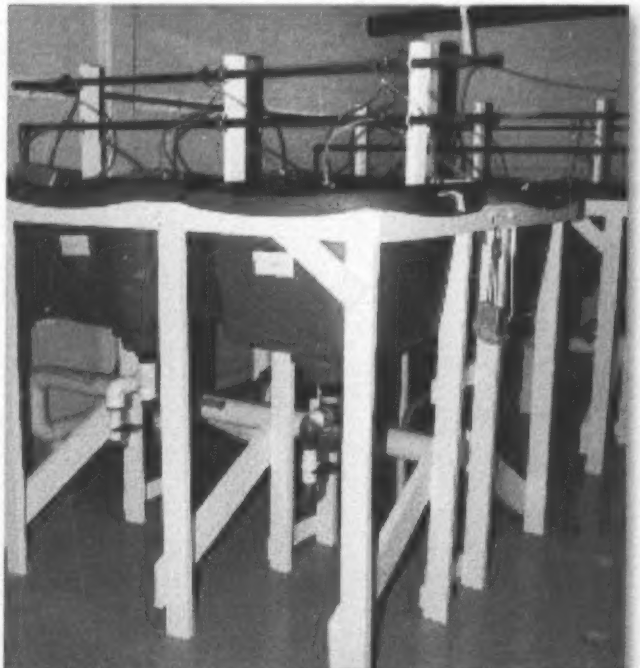
Objective 2: Determination of apparent digestibility coefficients (ADC) of the nine selected by-products.

Objective 3: Small-scale nutritional experiments to determine the optimal level of incorporation of the three selected by-products.

Objective 4: Large-scale physiological and nutritional experiments to determine the performance of the three selected by-products. This experiment will determine the commercial potential of the three novel by-products. The best by-products and feed formulation could be eventually commercialized by the aquaculture industry.

2009 – 2014 • Funded by: Atlantic Canada Opportunities Agency's Atlantic Innovation Fund (AIF), Institut de recherche sur les zones côtières (IRZC)
Project team: Sébastien Plante (UMCS), Jacques Gagnon (IRZC), Nadia Tchoukanova (IRZC), Francis LeBlanc (DFO), Mark Laflamme (DFO), Nellie Gagné (DFO), France Béland (IRZC) • Contact: Sébastien Plante (Sebastien.plante@umcs.ca)

Digestibility tanks for salmon feed experiments



Sébastien Plante (UMCS)

Development of novel RNA-based treatment against the infectious salmon anemia virus

Infectious diseases present a significant economic burden to finfish aquaculture industries and there is concern that these diseases may also negatively impact wild fish populations. Specifically, infectious salmon anemia virus (ISAV) is an important viral pathogen of salmonids that causes mass mortalities. It has remained a recurrent problem in Eastern Canada and Maine since the initial epizootics of 1996. There are currently no post-vaccination treatments available to combat ISAV infections in the fish's later stages of development.

We propose the development of a novel RNA interference-based vaccine against ISAV. RNA interference (RNAi) has been successfully used to combat viral infections in many vertebrate and invertebrate species, and offers the distinct advantage of being used both as a prophylactic vaccine, and as a treatment to combat the virus at the first signs of infection. Contrary to traditional vaccines, RNAi-based vaccines can be developed to be efficacious against all strains of a particular virus.

To date, we have analyzed sequence data and designed interfering RNA which could potentially target all known strains of the ISA virus. These sequences have been cloned and we are in the process of testing the interfering-RNAs in cultured cell lines.

Sep. 2009 – Mar. 2013 • Funded by: DFO – Aquaculture Collaborative Research and Development Program (ACRDP), Cooke Aquaculture Inc.
Project team: Mark Laflamme (DFO), Adrien Boudreau (DFO), Nellie Gagné (DFO), Keng Pee Ang (Cooke Aquaculture Inc.), Gilles Robichaud (Cooke Aquaculture Inc.)
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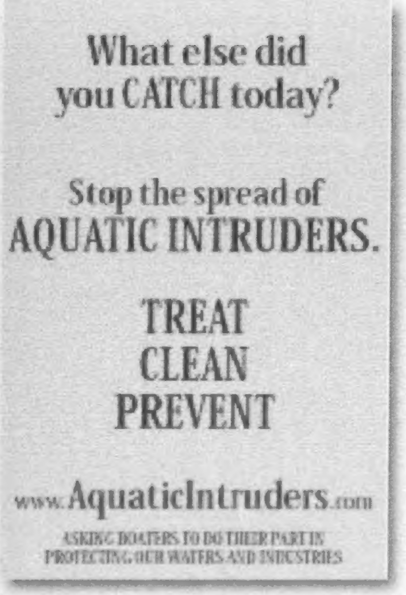
Development of molecular assays for the detection of *Perkinsus* species

Protozoan parasites of the genus *Perkinsus* infect many species of marine bivalves throughout the world. Recently developed assays, based on the PCR amplification of specific gene sequences, offer greater sensitivity and specificity than traditional tests; however, these tests are not in widespread use, and they have not been validated to the level expected from legal diagnostics laboratories. We propose to adapt existing PCR-based tests and/or develop new assays for the identification of pathogenic protists from the genus *Perkinsus*. We will use existing publicly available, genomic sequence data from all available species to design "updated" real time PCR assays.

The available genetic data suggests that there are sufficient DNA sequence similarities among the different *Perkinsus* species so that a single PCR-based test could be designed for the detection of the genus *Perkinsus* as a whole. Further, there are sufficient differences among the genetic sequences of these species so that individual species-specific real time PCR assays could be developed. We intend to develop probe-based real time PCR assays for both the above mentioned cases, i.e., a test capable of detecting the genus as a whole, and individual tests capable of detecting and identifying each individual *Perkinsus* species.

Apr. 2010 – Mar. 2011 • Funded by: DFO – Centre for Aquatic Animal Health Research and Diagnostics (CAAHRD)
Project team: Mark Laflamme (DFO), Jean René Arseneau (DFO), Mélanie Robichaud-Haché (DFO)
Contact: Mark Laflamme (Mark.Laflamme@dfo-mpo.gc.ca)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Information signage

PEI Aquaculture Alliance

Development of interactive and targeted educational resources to help control the spread of Aquatic Invasive Species (AIS) in Atlantic Canada

The objective of this project was to increase awareness about the spread of Aquatic Invasive Species (AIS) throughout Atlantic Canada and prevent the introduction of others (AIS) which are close by (e.g., *Didemnum vexillum* from the US) by targeting two key audiences: recreational boaters; and First Nations and Aboriginal Peoples Representative Organizations.

Hull fouling is a proven vector for the spread of AIS and boats visit Atlantic Canada from areas infested with AIS not yet present in Atlantic Canada. To target boaters across Atlantic Canada, a website has been developed that displays the locations for AIS on the eastern seaboard of North America and provides information on their impacts and treatments.

First Nations and Aboriginal groups are strongly involved in the fisheries and aquaculture sectors but have not been specifically targeted by previous AIS awareness efforts. Working in partnership with the Mi'kmaq Confederacy of PEI and The Native Council of PEI, new materials were developed and distributed through community events such as the Panmure Island Pow Wow and group Annual General Meetings.

Jun. 2009 – Mar. 2010 • Funded by: Invasive Alien Species Partnership Program, Mi'kmaq Confederacy of PEI, Native Council of Prince Edward Island, PEI Department of Fisheries, Aquaculture and Rural Development, Fisheries and Oceans Canada (DFO)
Project team: Peter Warris (Research and Development co-ordinator for PEI Aquaculture Alliance)
Contact: Peter Warris (rd@aquaculturepei.com) • www.aquaticintruders.com

Developing Camelina as the next Canadian oilseed

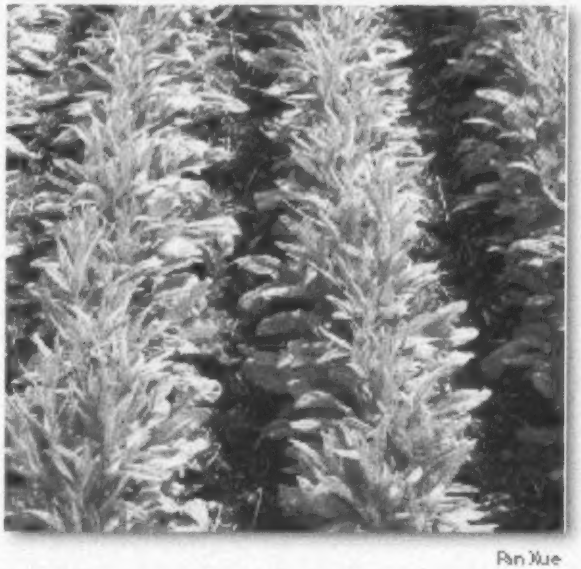
Feed is a major factor in overall profitability for aquaculture producers, making up 50-70% of total production costs. In particular, fish meal and oil, used for many carnivorous species, have fluctuating availability and prices.

Plant breeders and plant genomics specialists are working with fish nutritionists and fish functional genomics specialists to improve and evaluate Camelina tailored to meet the nutritional needs of commercial aquaculture finfish species.

The $6.1-million Camelina project aims to address this issue through the development of diets for cod, salmon and trout that substitute Camelina for some of the fish meal and oil. Camelina is a member of the mustard family with a well-balanced array of amino acids, making it a potentially viable replacement for fishmeal and other high protein feedstuffs. This hardy plant also has a desirable balance of omega-3 and omega-6 fatty acids, meaning fish species that accumulate intermuscular fat, such as trout and salmon, will deposit these fatty acids in proportion to their dietary intake.

The project aims to deliver:
- Improved lines of Camelina optimized for aquaculture feed applications.
- Digestibility information on Camelina seed and byproducts for salmonids and cod.
- The identification of salmon, trout, and cod gene expression biomarkers of responses to Camelina-based diets using functional genomic techniques.
- An assessment of the impact of Camelina-based diets on growth and biological processes.

May 2009 – Dec. 2014 • Funded by: Genome Atlantic, Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA-AIF), Nova Scotia Agricultural College, Memorial University of Newfoundland-Ocean Sciences Centre, Agriculture and Agri-Food Canada, Minas Seed Co-operators, Atlantic Oilseeds Ltd., Colorado State University, University of Giessen, Linnaeus Plant Sciences Ltd., Saskatchewan Ministry of Agriculture, Saskatchewan Canola Development Council, Nova Scotia Department of Agriculture, Nova Scotia Department of Fisheries and Aquaculture, New Brunswick Department of Agriculture, Aquaculture and Fisheries, Research Development Corporation of Newfoundland and Labrador, Western Economic Partnership Agreement – Western Economic Diversification Canada
Project team: Claude Caldwell (Nova Scotia Agricultural College), Isobel Parkin (Agriculture and Agri-Food Canada), Derek Anderson (Nova Scotia Agricultural College), Dwayne Hegedus (Agriculture and Agri-Food Canada), Chris Parrish (Memorial University of Newfoundland), Matthew Rise (Memorial University of Newfoundland), Cara Kirkpatrick, Camelina (Genome Atlantic), Genome Atlantic, Agriculture and Agri Food Canada Saskatoon Research Centre, Memorial University of Newfoundland, Ocean Sciences Centre, Nova Scotia Agricultural College, University of Saskatchewan, Minas Seed Co-operators, Atlantic Oilseeds Ltd., Linnaeus Plant Sciences Ltd., Colorado State University (USA), University of Giessen (Germany), National Research Council Plant Biotechnology Institute
Contact: Claude Caldwell (ccaldwell@nsac.ca) • www.genomeatlantic.ca


Camelina in fields

Pan Xue

Innovative sustainable solutions for Canadian finfish aquaculture operations

This AIMAP project allowed the first ever complete integration of the advanced AEG Feeder and AEG Containment Systems while including fish on a commercial, very high-energy grow-out site in St. Mary's Bay, NS. Smolt availability prevented full stocking of the site as originally planned but a lower number of smolt were entered to allow monitoring of fish welfare with the equipment. Further technology development occurred during this Phase I project, including proof-of-concept of a submersible HDPE collar that saved the equipment/fish from ruin in February 2009 when heavy ice passed through the site and integration of the AquaSonar fish sizing technology with the AEG Feeder to measure fish size on a regular basis. AEG continues to develop logistics mitigation strategies that increase farm safety, fish welfare, and cost-effectiveness. A primary example of this from Phase I involves the new AEG nursery net system that effectively concentrates small smolts for better fish and feed management during the early days following sea cage entry while increasing survival by providing a more protected environment even in the open ocean. Completed activities in Phase I will continue to be monitored during Phase II as these technologies support our activities to raise fish on this established high-energy site in the Bay of Fundy. Value engineering, environmental and economic evaluation, AEG Solutions demonstration, and new product development, as necessary, will continue and be the focus of Phase II activities.

Oct. 2008 – Mar. 2010 • Funded by: DFO – Aquaculture Innovation and Market Access Program, AEG, NSDFA, ACOA, NRC-IRAP
Project team: Chris Bridger (AEG), Philip Dobson (AEG), Wade Landry (AEG), Dave Hoar (MotionDesign) • Contact: Chris Bridger (chris.bridger@aeg-solutions.com)

Skills development for sustainable aquaculture and fish preservation – education for employment program – Mozambique

The Mozambican government has embarked upon an ambitious project to professionalize its workforce in key primary resource sectors such as agriculture, fisheries, aquaculture, forestry and others. Both fisheries and aquaculture are key development priorities for the people of Mozambique. The overall goal is to alleviate poverty while contributing to gender equity, improved access to education and health in the country. The Marine Institute, in partnership with the Mozambican national agriculture school (Instituto Agrario de Mocuba) and the Collège Communautaire du Nouveau-Brunswick in Caraquet, is assisting with the development of competency-based educational programs in aquaculture and fish preservation in Mozambique focusing on the applied technology and entrepreneurship aspects. This will enable the sector from the small farm-owner/operator level to large intensive marine shrimp farmers to avail of a highly qualified, nationally certified workforce. The group is working in collaboration with the Centro de Formaçao Profissionnal de Quelimane, Mozambique, to develop short, community-based training programs in fish culture and preservation so that training can be delivered at the farm level. The project is in its second year and curriculum development and validation as well as professor training is ongoing. New collaborations have been developed with the University Eduardo Mondlane's aquaculture program and faculty, as well as with the Directorate of Aquaculture in the Mozambique Department of Fisheries. One of the unanticipated outcomes of the project so far has been increased collaborations in the training of highly qualified personnel for the national university in Mozambique, as well as in the initiation of technology transfer efforts with the country's commercial aquaculture sector.

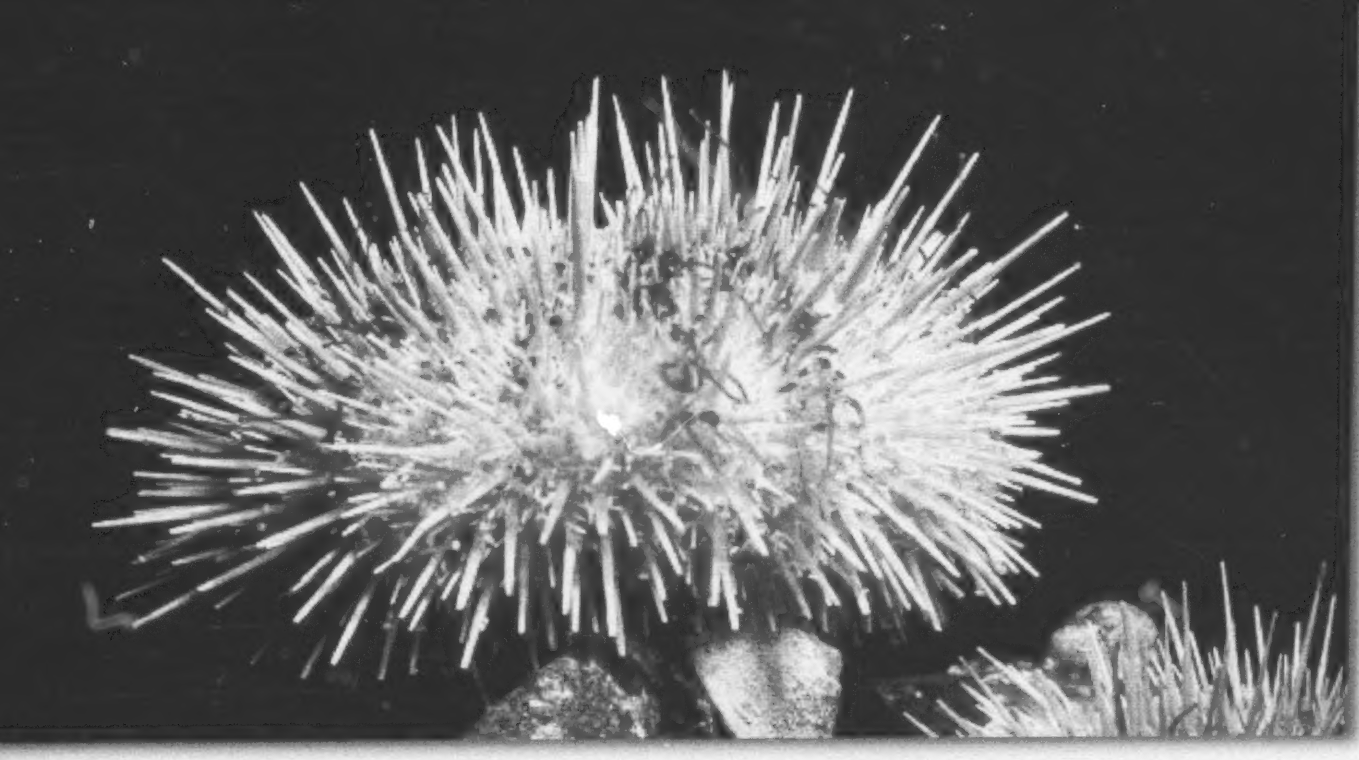
Oct. 2009 – Jun. 2012 • Funded by: Canadian International Development Agency (CIDA), Marine Institute of Memorial University, Association of Canadian Community Colleges, Collège Communautaire du Nouveau-Brunswick à Caraquet, Government of Mozambique Aquaculture Directorate and Department of Education
Project team: Cyr Couturier, Hilario Canga, Joao Ubisse, Glen Penney, Luc Theriault, Antonio Hoguane (University Eduardo Mondlane), Isabel Omar (Director Mozambique Fisheries Department, Aquaculture Division, Maputo) • Contact: Cyr Couturier (cyr@mi.mun.ca) • www.mi.mun.ca/casd

ESCOLA SUPERIOR
MARINHAS

Educational team in Mozambique

Local fish seller in Mozambique

Cyr Couturier (MUN)



Shawn Robinson (DFO)

Fisheries and Oceans Canada's Research and Development Programs Supporting Canadian Aquaculture

DFO's vision for aquaculture development in Canada is "to benefit Canadians through the culture of aquatic organisms while upholding the ecological and socio-economic values associated with Canada's oceans and inland waters." On behalf of the Government of Canada, DFO facilitates this vision by delivering programs and services that support Canada's scientific, social, and economic interests in oceans and fresh waters and through delivering the following outcomes to Canadians:

- Economically Prosperous Maritime Sectors and Fisheries
- Sustainable Aquatic Ecosystems
- Safe and Secure Waterways

In order to deliver these outcomes, DFO has developed several programs that provide a strong scientific foundation and effective management to both support the economic prosperity of the aquaculture industry and ensure the sustainability of Canada's aquatic ecosystems.

DFO is the lead federal department for the sustainable management of fisheries and aquaculture. Responsibility for aquaculture management and development (governance) is shared with provincial and territorial governments to ensure that the legislative and regulatory framework for aquaculture is responsive to the needs of industry and Canadians.

In order to focus research, DFO has developed aquaculture pathways of effects (POEs) describing aquaculture activity - stressor - effect linkages for each of seven pathways: chemicals, escapes, light, noise, nutrients, pathogens, and structure. Knowledge gaps and research recommendations for each pathway were identified through a science advisory process and will aid DFO in creating research priorities for ACRDP and PARR. The goal will be to target research priorities that clearly meet the needs of federal, provincial, or territorial regulators and managers. www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2009/2009_071-eng.htm

DFO's aquaculture research is supported by four key programs focussing on:

- regulatory knowledge gaps in support of federal and provincial aquaculture regulations, including since December 2010, research priorities to support the federal Pacific Aquaculture Regulations (Program for Aquaculture Regulatory Research)
- collaborative research and development to increase the level of collaborative research and development activity between the aquaculture industry and DFO (Aquaculture Collaborative Research and Development Program)
- the development of genomic tools used in disease diagnostics and broodstock development (Genomics Research and Development Initiative)
- collaborative projects that facilitate the transfer of the latest technologies from research and development to the commercialization stage for use by the aquaculture industry (Aquaculture Innovation and Market Access Program)

These four programs that fund aquaculture research and development are described in detail below.

Aquaculture Collaborative Research and Development Program (ACRDP)

The Aquaculture Collaborative Research and Development Program (ACRDP) is a DFO initiative to increase the level of collaborative research and development activity between the aquaculture industry and the department, and in some instances with other funding partners. The ACRDP is an industry-driven program that teams industry with DFO researchers. Projects are conducted at DFO Research facilities or possibly industry partner facilities. The program allocates ACRDP funds to collaborative research projects that are proposed and jointly funded by aquaculture producer partners. The ACRDP funding is approximately $4.275 million per year and is subdivided regionally.

The key goals of the program are to improve the competitiveness of the Canadian aquaculture industry, increase collaboration between the department and industry to enhance aquaculture in Canada, facilitate and accelerate the process of technology transfer and research commercialization, and increase scientific capacity for essential aquaculture research and development in the aquaculture sector.

The broad research and development objectives, under which National and Regional priorities have been established, are threefold:

- Best performance in fish production;
- Optimal fish health;
- Industry environmental performance.

Since the program's inception in 2001, over 320 projects have been approved and funded. In total, almost $70.0M in research has been funded through the ACRDP, consisting of $32.5M in ACRDP funds, $15.4M in industry contributions, $5.0M leveraged from other project partners, and $17.0M that DFO has contributed on top of the yearly ACRDP allocation.

Contact: Corinne Busby (Corinne.Busby@dfo-mpo.gc.ca)
For more information, please visit the ACRDP website at:
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Genomics Research & Development Initiative (GRDI)

Through the adoption of leading-edge genomics research and biotechnology tools and techniques, Fisheries and Oceans Canada is improving it's ability to protect endangered species, manage opening and closing of fisheries, avoid overexploitation of resources, prosecute poachers, improve aquaculture practices, control disease outbreaks, and remediate contaminated sites. This focus is strategically aligned with federal priorities for science and technology related to environmental sustainability, scientific support for regulatory and policy decisions, and utilizing cutting-edge technology within federal science-based departments to manage the diverse range of human activities in Canadian waters.

The Genomics Research and Development Initiative (GRDI) sustains intramural genomics research in support of key federal public policy objectives in areas of national interest to strengthen innovation, promote competitiveness, and ensure sustainability for the benefit of Canadians. Since the implementation of the GRDI in 1999, participating departments and agencies (National Research Council of Canada, Agriculture and Agri-Food Canada), Health Canada and the Public Health Agency, Natural Resources Canada, Environment Canada and Fisheries and Oceans Canada) have increased their human resource capacity as well as enhanced the tools, equipment, infrastructure and networks required to undertake genomics research and development and participate in broader, high-impact programs through extensive collaborations with Canadian and international organizations.

Contact: Mark Hovorka (Mark.Hovorka@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/Science/biotech/grdi-irdg/index-eng.htm
Further information on priorities, plans, programs and projects can be found on the DFO web site: www.dfo-mpo.gc.ca.

Program for Aquaculture Regulatory Research (PARR)

The Program for Aquaculture Regulatory Research (PARR) is an internal DFO research program that supports research projects focused on increasing the relevant science knowledge base that supports and advises informed DFO ecosystem-based environmental regulation and decision making for the aquaculture sector.

This program was created in 2008 as part of the Sustainable Aquaculture Program. The knowledge and information produced as a result of funded research will support federal, provincial and territorial activities to develop ecosystem-based approaches for the management of aquaculture.

Research priorities for PARR are targeted to address regional and national regulatory research priorities, focusing on understanding aquaculture-environment interactions to support siting considerations and science to support fish health management, including research to support sea lice management and the fate and effects of sea lice treatments on non-target organisms.

Contact: Nancy House (Nancy.House@dfo-mpo.gc.ca)
www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp

Aquaculture Innovation and Market Access Program (AIMAP)

In 2008 DFO announced a new grants and contributions program to bolster the development, early commercialization and/or early adoption of innovative techniques for the Canadian aquaculture sector. Over the next five years $23.5 million will be made available for innovation and market access projects.

The goal of this new program is to catalyze private sector and other investment in the aquaculture sector that will:

- Improve the competitiveness of the Canadian aquaculture industry by encouraging an aquaculture sector that continuously develops and adopts innovative technologies and management techniques to enhance its global competitiveness and environmental performance; and
- Position Canadian aquaculture products as having high value in the market place based on their environmental performance, traceability and other considerations.

Since June 2008 AIMAP has contributed approximately $15 million towards 106 projects totalling $58.5 million in value. These projects are contributing towards the program goals of development of high value products, sustainable development, species diversification or the development of green technology.

www.dfo-mpo.gc.ca/aquaculture/sustainable-durable/innovation-eng.htm

Nellie Gagné (DFO)

NSERC investments in aquaculture R&D partnerships soar to historic highs

Investments in aquaculture research partnerships by the Natural Sciences and Engineering Research Council (NSERC) and its partners in industry and government have soared to historic highs in recent years. This has been fuelled by the federal government's current emphasis on addressing the innovation needs of fisheries and related industries.

In fiscal year 2009-10, NSERC investments in university-industry aquaculture research partnerships topped $4.6 million – almost 2.5 times more than the average annual outlay during the previous 10 years. That investment leveraged a record $2.7 million in cash and in-kind contributions from partners in industry and government, a staggering seven-fold jump since the 2000-01 fiscal year.

Fisheries and related industries were among four industry sectors identified as priorities for NSERC research partnership investments in Budget 2008. To address these priorities, NSERC received an additional $34 million annually.

In the past two years alone, NSERC has committed more than $24 million to fisheries and aquaculture research partnerships. This funding has supported more than 25 research projects and two Strategic Networks, including the NSERC Canadian Integrated Multi-Trophic Aquaculture Network.

NSERC's Collaborative Research and Development (CRD) program and DFO's Aquaculture Collaborative Research and Development Program (ACRDP) both support aquaculture industry collaborative research. As these programs are complimentary, collaborative teams of aquaculture researchers from academia, DFO and industry could apply for matching funds under both programs. NSERC and DFO are looking at ways to facilitate the evaluation of proposals simultaneously submitted under these collaborative research programs. Additionally, the potential also exists for NSERC and DFO to jointly sponsor workshops also aimed at creating new partnerships among industry, academic, and government researchers.

www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/CRD-RDC_eng.asp

New Industry-driven Strategy

Complementing the joint workshops is NSERC's new Engage Grants Program (EGP), which helps university researchers build new, sustainable partnerships with Canadian companies. Engage provides grants of up to $25,000 for six months to help researchers solve company-specific technological challenges. So far the program has been a smash hit with researchers and businesses alike, with more than 400 Engage Grants awarded in 2010 alone.

The Engage program is one of several new initiatives that have emerged from NSERC's new Strategy for Partnerships and Innovation (SPI), unveiled in November 2009. Developed with extensive input from industry, SPI is an action plan with four main thrusts that have been identified in cooperation with industry: building sustainable relationships; streamlining access to partnership funding programs; connecting people and skills; and, focusing on national priorities. The over-arching goal of this four-point Strategy is to more than double the number of companies participating in NSERC-funded research partnerships to approximately 3,000 by 2014.

While Engage Grants are a key instrument for meeting this objective, NSERC is also moving on several other fronts to attract more businesses to research partnerships, including:

- Refining the mandate of its five regional offices – Atlantic, Quebec, Ontario, Prairies and Pacific - to focus squarely on facilitating academic-industry research collaborations;
- Organizing "speed dating" events to bring interested researchers and companies into brief and structured contact to discuss needs and capabilities;
- Supporting project management within our partnership grants;
- Offering grants to researchers in support of market studies to assist in commercializing promising inventions and to inform research directions; and
- Improving our intellectual property (IP) policy to expand arrangement options between industry and post-secondary institutions, including assignment of IP rights to industry partners.

In addition to these actions, NSERC has significantly expanded the range of funding opportunities for businesses that want to tap into expertise in Canada's Community Colleges and CEGEPS. For example, under the Colleges and Community Innovation Program, NSERC has introduced new Applied R&D Grants that will assist college experts in solving company-specific problems.

During the last two years, there have been important new developments at NSERC. These have been geared to helping companies benefit from the enormous federal investment in post-secondary research and student training. To stay informed about what's going on at NSERC, researchers can subscribe to NSERC's new e-bulletin, IN Partnership. Readers will be able to keep abreast of new funding opportunities and learn more about how Canadian companies are prospering from NSERC-funded research partnerships.

NRC-IRAP supports aquaculture SMEs to grow stronger, grow faster and grow bigger through innovation

NRC Industrial Research Assistance Program (NRC-IRAP) supports small- and medium-sized enterprises (SMEs) in Canada to enable them to grow stronger, grow faster, and grow bigger and larger through innovation and technology.

Delivered through a network of over 240 Industrial Technology Advisors (ITAs) found in more than 100 communities across Canada, this Program helps firms to develop technologies and successfully commercialize them in a global marketplace. It provides a suite of advisory services, networking and linkages, and non-repayable financial assistance to SMEs. These services are adapted to the SMEs industrial, socio-economic, and geographic make-up of the SMEs in order to provide a customized response to their development needs.

Since April 1, 2009, NRC-IRAP has provided $3,190,588 in financial support to aquaculture SMEs across Canada. This has been applied to 65 different projects to aquaculture SMEs across Canada to assist them in their new product and process development and improvement, and in adoption initiatives. Here are some examples of program assistance provided to the aquaculture sector during this period:

- NRC-IRAP supported an incoming technology transfer mission for TRI-GEN Fish Improvement Ltd. (Bruce Swift: bruceswift@shaw.ca), a BC salmon farming company, to bring Cryogenetics AS of Norway to demonstrate their finfish milt cryopreservation technology. Cryogenetics has now incorporated a subsidiary, Canada Cryogenetics Services Inc., who will offer their services to finfish aquaculture companies across the country.
- NRC-IRAP Youth Employment Program supported Quebec-based Aquabiotech Inc. (Hélène Drouin: info@aquabiotech.ca) to hire an intern who worked on developing rearing pond habitat for zebrafish and *Xenopus* frogs. Under the same program, Carter's Point, NB's Acadian Sturgeon and Caviar Inc. (Cornel Ceapa: cceapa@acadian-sturgeon.com) hired an intern to study the impact of physical rearing conditions on growth in early life stages of cultured sturgeon.
- NRC-IRAP provided financial support to Lyndon Fish Hatcheries Inc. of New Dundee, Ontario (Lynn Rieck: lynnrieck@mail.com) who is collaborating with Rainbow Trout farmers in Atlantic Canada on the development of strains with better growth performance for saltwater sea cage grow-out.
- NRC-IRAP linked Newfoundland seafood processor Allen's Fisheries Ltd. (Sean Allen: sallen@allensfisheries.com) to Memorial University's Marine Institute, which provided technical input and financial support toward the successful development of a long-term live holding system for farmed mussels.

In 2002, NRC-IRAP worked with industry associations the New Brunswick Salmon Growers Association, the Aquaculture Association of Nova Scotia, the Newfoundland Aquaculture Industry Association and the PEI Aquaculture Industry Alliance to establish what's now known as the Atlantic Canada Aquaculture Research and Development Network (ACAIRDN), placing R&D Coordinators (RDCs) in each of the associations. Since that time, NRC-IRAP has supported RDCs in associations in BC, Ontario, Quebec and in the NB shellfish industry. The presence of ACAIRDN and individual RDCs has increased the technical acumen of sector associations enabling tech transfer to their members, establishing and communicating sector R&D priorities to stakeholders, increasing R&D coordination within the sector and access to outside expertise for their members.

For more information on the program and to contact your local NRC-IRAP ITA, please call 1-877-994-4727 or send an email to publicinquiries.irap-pari@nrc-cnrc.gc.ca

GenomeBC

Genome BC

Genome BC's research projects tackling major aquaculture challenges

The largest industry in BC's $1.9 billion fisheries sector, aquaculture includes both ocean and inland fish farms. Dominated by salmon, oysters and clams, the total harvest in 2007 was 88,900 tonnes, generating $388 million in revenues and $116 million in GDP. Farmed salmon accounts for 94% of total farm gate value from aquaculture in the province, positioning BC as the fourth largest producer of farmed salmon in the world.

But innovative solutions are urgently needed to sustain and expand production. Genome sciences are assisting in the development of improved management strategies to protect biodiversity and maintain the health of both marine and freshwater species. Genomics research is also providing novel technologies for selecting production and quality traits to ensure fisheries and aquaculture industries provide high-value products.

Genome BC's research projects are tackling major challenges to the fisheries and aquaculture industries including sea lice, climate change and increased demand for food products. Projects aim to provide a better understanding of the effect of environmental changes on fish and other aquatic species, the effects of toxic algae and diseases, and the interaction of pathogens and parasites. Applications and technologies from this research include tools that forecast responses to environmental stressors and changes; methods for monitoring viral, bacterial or fungal pathogens and parasites to improve prediction and treatment of disease outbreaks; and support for novel methods to control algae blooms around fish farms.

Example projects:

Development of a health assessment tool for marine mussels (Myt-OME): Measuring environmental impacts on mussel health

Funded by Genome BC, the team is developing a sensitive genomic tool for multiple species of marine mussels, which will enable more accurate health assessments of coastal zones and aquaculture operations and help monitor the effects of the changing environment. Current methods to measure environmental impacts on mussel health are time-consuming and use mainly unreliable physiological indicators.

Atlantic salmon genome: Genome BC teaming up with international partners to sequence the Atlantic salmon genome

The multi-phased project's goal is to produce a genome sequence that identifies and maps the genes in the Atlantic salmon. This genome will then act as a reference and guide sequencing of the genomes of other salmonids, including Pacific salmon and rainbow trout, and more distantly related fish such as smelt and pike.

Genomic Tools for Fisheries Management (FishMan Omics): Assessing the health of BC's wild salmon industry

This Genome BC-funded project, as led by the University of British Columbia's Scott Hinch and Kristi Miller of Fisheries & Oceans Canada, is using genomics to characterize biomarkers to assess the overall health and condition of migrating fish stocks.

Sablefish Genomics: Understanding genetic variation in sablefish

Funded by Genome BC, the Sablefish Genomics project developed a preliminary suite of genomic tools that can provide important information to both aquaculture companies and management of wild fish stocks. University of Victoria's Ben Koop, in collaboration with Sablefish Canada Ltd., identified and characterized the genetic variation in sablefish, allowing for efficient identification of individuals for monitoring wild stocks as well as for selective breeding programs for aquaculture.

Genomics in Lice and Salmon (GiLS): Using genomics to combat sea lice infections in salmon

The Genome BC-funded team of researchers (University of Victoria's Ben Koop, Simon Fraser University's William Davidson, Fisheries & Oceans Canada's Simon Jones, and Vancouver Island University's Grant Murray) is using microarray technology to examine gene expression patterns of both salmon and louse to identify which genes undergo significant changes in expression during infection. Identification of genetic markers in lice will enable the examination of population characteristics, including migration patterns, origins and selection, which will in turn provide information about the genetic factors that influence the host-pathogen response.

www.genomebc.ca

Summary of ACOA's role and investments in Atlantic Canada's aquaculture industry

Established in 1987, the Atlantic Canada Opportunities Agency (ACOA) is the federal agency responsible for the Government of Canada's economic development efforts in the provinces of New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador. With 30 offices throughout Atlantic Canada, ACOA works with business and communities to make Atlantic Canada's economy more innovative, productive and competitive. In addition, ACOA ensures that Atlantic Canada's interests are reflected in both the policies and programs developed by other departments and agencies of the federal government.

ACOA has a broad mandate to increase employment opportunities and earned income in the Atlantic region. The Agency has identified aquaculture as one of several strategic sectors for Atlantic Canada. Through the Atlantic Innovation Fund (AIF) and the Business Development Program (BDP), ACOA has worked in partnership with industry stakeholders to make investments in innovation and infrastructure that build upon the aquaculture industry's competitive advantages. For instance, over the last 10 years, ACOA has made AIF contributions towards the following R&D aquaculture projects:

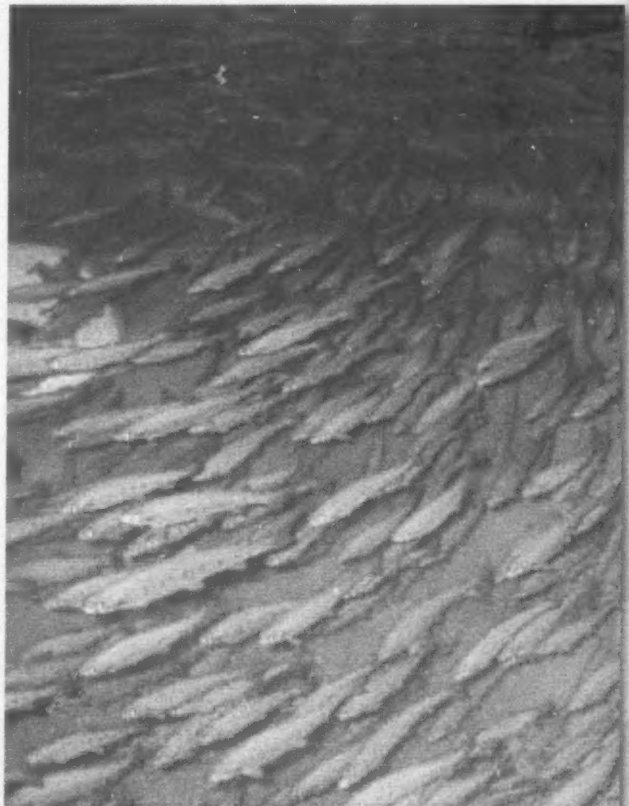
Aquaculture R&D Projects related to fish:

- Genome Atlantic (Pan Atlantic): Atlantic Cod genomics and broodstock development to enhance the commercialization of the cod aquaculture industry
- University of New Brunswick (NB): Integrated multi-trophic aquaculture research and development to mitigate the environmental impact of marine cage culture
- University of New Brunswick (NB): Effluent treatment system for land based aquaculture to mitigate effluent discharge
- Novartis Animal Health Canada (PEI): Platform development and DNA vaccine for kio herpes virus
- Université de Moncton (NB): Broodstock research and development related to high pedigreed Arctic Charr to enhance commercialization opportunities
- Scotian Halibut Limited (NS): Develop certified halibut broodstock to enhance commercialization opportunities
- Huntsmen Marine Science Centre (NB): Develop an Atlantic Salmon broodstock facility to enhance commercialization opportunities
- Research Productivity Council (NB): Develop a new fish pathogen diagnostic tool for the aquaculture industry
- Memorial University (NL): Support for Atlantic Cod broodstock development and fish health management protocols to enhance commercialization opportunities for the aquaculture industry
- Atlantic Veterinary College (PEI): Create a Centre for Aquatic Health Sciences to support the regions aquaculture industry
- Genome Atlantic (PEI): Development of Camelina as a feed supplement for the aquaculture industry
- Aqua Bounty Canada Inc. and Aqua Bounty Farms Inc. (PEI): Generate technology to produce reproductively sterile Atlantic Salmon
- Atlantech Engineering & Associates Incorporated (PEI): Advancing water recirculation and effluent treatment technology for the land-based aquaculture industry
- Solarvest (PEI) Inc.: Microalgae oils for salmon feed nutraceutical application
- Cooke Aquaculture Inc. (NB): Development and implementation of aquaculture stock traceability
- Novartis Animal Health Canada Inc. (PEI): Mitigation of infectious salmon anemia (ISA) by vaccination and genetic selection

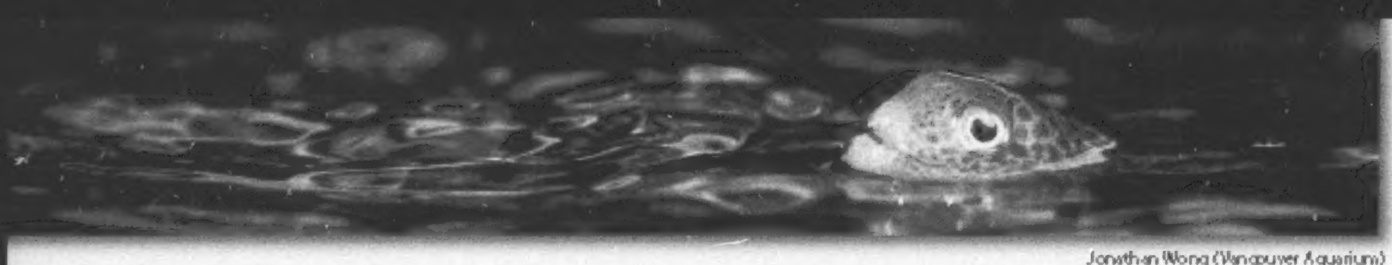
Aquaculture R&D Projects related to Shellfish and Seaweeds

- PEI Aquaculture Alliance (PEI): Management of invasive species (e.g., tunicates) fouling aquaculture farms
- Université de Moncton (NB): Technology and services to enhance the commercialization of the Shellfish (e.g., oysters) industry
- Acadian Seaplants Limited (NS): Cultivate seaweed biomass for human food and biomass for active compounds for use in various sectors (e.g., agriculture, nutrition)

www.acoa-apeca.gc.ca



DFO



Jonathan Wong (Vancouver Aquarium)

Genome Canada

Genome Canada is a not-for-profit organization established in February 2000 with a Government of Canada mandate to develop and implement a national strategy to support large-scale genomics and proteomics research projects that benefit all Canadians.

Fisheries and aquaculture is one of Genome Canada's six areas of focus, and, as of 2010, it had enabled over $43 million in related genomics research, roughly $21 million of that coming from Industry Canada via Genome Canada, and the other half coming from a variety of public and private sources.

Genome Canada competitions adhere to world-class peer reviews, and are focused on research projects with strong potential for application. Projects typically have efficient collaborations between industry, academia and government representatives, and have become globally-recognized for their work in advancing this sector in terms of genomics as well as policy, commercialization and knowledge translation issues.

Project results are communicated as broadly as possible, via industry and other relevant publications, as well as venues such as aquaculture association and scientific conferences and meetings.

Genome British Columbia and Genome Atlantic, given their proximity to substantial aquaculture industry, have managed much of the aquaculture related projects funded by Genome Canada, and have collaborated on many aspects of these projects, creating a national network of expertise in the process.

Results from the projects have included:

- The International Genomics Research in Atlantic Salmon project (GRASP) and subsequent Consortium for Genomics Research on all Salmonids Project (cGRASP) have developed a set of evidence-based genomic resources for salmonids (salmon, trout, charr). These tools are helping industry, government and academia and environmental conservationists confront challenges ranging from amoebic gill disease in Australia to municipal waste monitoring in Europe and Canada. (GRASP 2001-2005) (cGRASP 2006-2010)
- Finding the genes related to growth and other traits of interest to the Canadian halibut aquaculture industry, which has enhanced their breeding programs and reduced time to market by 20%, greatly increasing profitability. (Pleurogene Project, 2005-2008)
- Increasing productivity and innovation in the Canadian cod aquaculture industry through the discovery of the genes associated with disease-resistance, growth rates and stress tolerance. (The Atlantic Cod Genomics and Broodstock Development Project, 2006-2010)

Because of the enormous potential for aquaculture to be an economic driver in Canada, Genome Canada continues to include this sector within its six priority areas, and actively seeks the input of industry and government regarding the issues of most importance.

www.genomecanada.ca

Genome Atlantic

With the incredible potential that aquaculture holds for Canada, Genome Atlantic has made aquaculture a major element of its research portfolio. The organization, along with the Government of Canada through Genome Canada and many other regional partners, has enabled over $27 million in aquaculture-related genomics projects aimed to increase productivity and reduce costs for Canadian aquaculture producers.

Projects have ranged from roughly $4 - $18 million, and have attributed their considerable results to the collaborative nature of the research, where genomics-based solutions were developed to address key industry challenges.

The projects have dealt with a variety of issues ranging from elite broodstock development to the study of sustainable feeds to replace fishmeal and oil.

Significant results to date have included:

- Finding the genes related to growth and other traits of interest to the Canadian halibut aquaculture industry, which has enhanced their breeding programs and reduced time to market by 20%, greatly increasing profitability. (Pleurogene Project, 2005-2008)
- Increasing productivity and innovation in the Canadian cod aquaculture industry through the discovery of the genes associated with disease-resistance, growth rates and stress tolerance. (The Atlantic Cod Genomics and Broodstock Development Project, 2006-2010)

A current project (Camelina: Canada's Next Oilseed, 2010-2013) is exploring the potential of camelina, a hardy, oil-rich plant, as a partial replacement for fish oil and meal in aquaculture feed. The plant's high levels of protein make it a strong contender for inclusion in fish feed, and could help reduce the cost and sustainability issues associated with fishmeal and oil. Camelina is already used in other animal feeds - including poultry - with great success. The project is conducted at the Nova Scotia Agricultural College and the Memorial University Ocean Science Centre, along with Agriculture and Agri-Food Canada, and is funded regionally by organizations such as the Atlantic Canada Opportunities Agency – Atlantic Innovation Fund for the Atlantic portion, and the Western Economic Partnership Agreement – Western Economic Diversification Canada for the Prairie component.

Aquaculture continues to be a focus of Genome Atlantic. The organization is actively seeking input from producers and government on areas of priority for this important sector.

Contact: Shelley King, Director of Project Management, Genome Atlantic (sking@genomeatlantic.ca) www.genomeatlantic.ca

Ministry of Agriculture, Fisheries and Food (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec – MAPAQ)

The Ministry of Agriculture, Fisheries and Food (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec – MAPAQ) promotes sustainable development and competitiveness in the fisheries and aquaculture sector in Quebec.

Its management of innovation and technology supports programs of scientific research and technical support to the industry led by its three R&D centres: the Centre for Mariculture Îles-de-la-Madeleine (Centre maricole des Îles-de-la-Madeleine – CeMIM), the Marine Aquaculture Centre Grande-Rivière (Centre aquacole marin de Grande-Rivière – CAMGR), and the Aquatic Products Technology Centre in Gaspé (Centre technologique des produits aquatiques, à Gaspé – CTPA). They generate knowledge useful to industry and coordinate technical assistance provided to aquaculture businesses through a network of contributors located throughout the province.

MAPAQ is responsible for developing and implementing strategies and programs that foster innovation. It provides funding for programs such as monitoring, R&D projects, technology transfer, and dissemination of information, and encourages collaboration among industry, institutions, and R&D organizations. Finally, mandated by the Government of Québec, MAPAQ oversees two funds managed by the mariculture industry development corporation (Société de développement de l'industrie maricole – SODIM) and the inland aquaculture research and development corporation (Société de recherche et de développement en aquaculture continentale inc. – SORDAC). It also provides funding to R&D organizations such as the North Shore Aquaculture Centre (Centre aquacole de la Côte-Nord), the Salmonid Selection and Transfer Centre (Centre de transfert et de sélection des salmonidés), and the Marine Biotechnology Research Centre (Centre de recherche sur les biotechnologies marines).

www.mapaq.gouv.qc.ca/fr/Pages/Accueil.aspx

Société de développement de l'industrie maricole (SODIM)

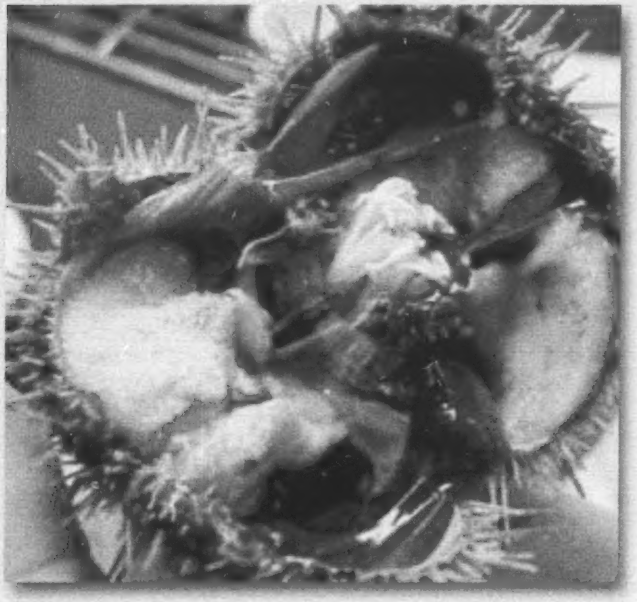
Société de développement de l'industrie maricole (SODIM) Inc. was founded in 1997 for the purpose of providing firms interested in marine aquaculture with flexible financial assistance tailored to their needs. SODIM is a not-for-profit corporation and its mission is to contribute to the creation and development of profitable, competitive marine aquaculture enterprises.

To achieve its mission, SODIM has set the following goals to promote the development of a viable marine aquaculture industry within its territory, namely in the Gaspé Peninsula, Magdalen Islands, Lower St. Lawrence and North Shore, specifically by:

- Providing financial assistance for the start-up, diversification and expansion of marine aquaculture enterprises;
- Offering technical assistance and advisory services to marine aquaculture enterprises; and
- Promoting research and development and technology transfer in aquaculture.

SODIM has two important tools with which to achieve its mission - an investment fund and a R&D fund. The general purpose of the R&D fund is to stimulate research and technology transfer and promote the development of fresh water and marine aquaculture enterprises in the maritime regions of Quebec. The fund is designed to support pre-competitive research activities, i.e., activities of a very practical nature. With the fund, SODIM seeks to promote innovation in the aquaculture industry in these regions. With the collaboration of its partners, SODIM is responsible for identifying research priorities and developing and overseeing the implementation of a science action plan.

www.sodim.org



Sea urchin Shawn Robinson (DFO)

The Réseau Aquaculture Québec

The Réseau Aquaculture Québec (RAQ) is a network of researchers (academic, provincial and federal government researchers, CEGEP professors) involved in aquaculture research in Québec. The network has been supported by Valorisation Recherche Québec (VRQ) and the Société de développement de l'industrie maricole (SODIM) from 2001 to 2006. From 2006 to 2012, the network will be supported through the "Réseaux stratégiques" program of the Fonds québécois de la recherche sur la nature et les technologies (FQRNT).

RAQ has succeeded in bringing together all Québec researchers with an interest in finfish and shellfish aquaculture, in both the fresh and marine environments, and to provide them with a forum for comparing and combining their research results and expertise.

RAQ has always had very close contact with the aquaculture industry in Québec, especially to its close association with SODIM and the Société de recherché et de développement en aquaculture continentale (SORDAC), partners who play an active role in the elaboration of the RAQ's scientific program.

Contact: Céline Audet, Ph.D. Scientific Director, celine_audet@uqar.qc.ca
http://raq.uqar.ca/

GenomeBC

Société de recherche et de développement en aquaculture continentale (SORDAC) Inc.

Société de recherche et de développement en aquaculture continentale (SORDAC) Inc. was created as an independent not for profit corporation in 1993 to coordinate and fund research and technology transfer in freshwater aquaculture in Quebec.

SORDAC's board has 11 directors, five from private industry, four from education institutions, and two from the public sector. Its members, mostly represented by active farmers, constitute over 80% of aquaculture production for consumption and stocking in Québec.

The mission of the SORDAC is to coordinate priorities and actions to enable funding of research and technology transfer. It also promotes effective networking between research partners and the aquaculture industry to increase the productivity and profitability of the Quebec freshwater aquaculture industry.

The SORDAC mission mandate is:

1. To develop and implement a strategy for research and technology transfer;
2. To encourage and fund research activities that are beneficial to the freshwater aquaculture sector in Québec;
3. To organize and finance the technology transfers to enterprises; and
4. To source funds to finance its activities.

Pacific Salmon Forum

The BC Pacific Salmon Forum completed its mandate to the Province of British Columbia with the delivery of a final report and recommendations in January, 2009. It has operated since April 2005 as an independent citizen body using science and stakeholder dialogue to advance the sustainable governance of BC Pacific salmon. Since 2006 it has funded a variety of research initiatives and technical reports.

Before ending operations, the Forum funded several initiatives to be carried out in spring and summer 2009, including:

- oceanographic data collection to support the refinement of the dynamic finite volume coastal ocean model tracking the movement of sea lice and other particles in the Broughton Archipelago;
- marine monitoring and analysis of wild juvenile pink and chum salmon in the Broughton Archipelago during the out-migration period of March through June; and
- lab and field study of the biological effects of SLICE®, (emamectin benzoate), a widely used anti-parasitic agent used on salmon farms to control sea lice, on the marine environment.

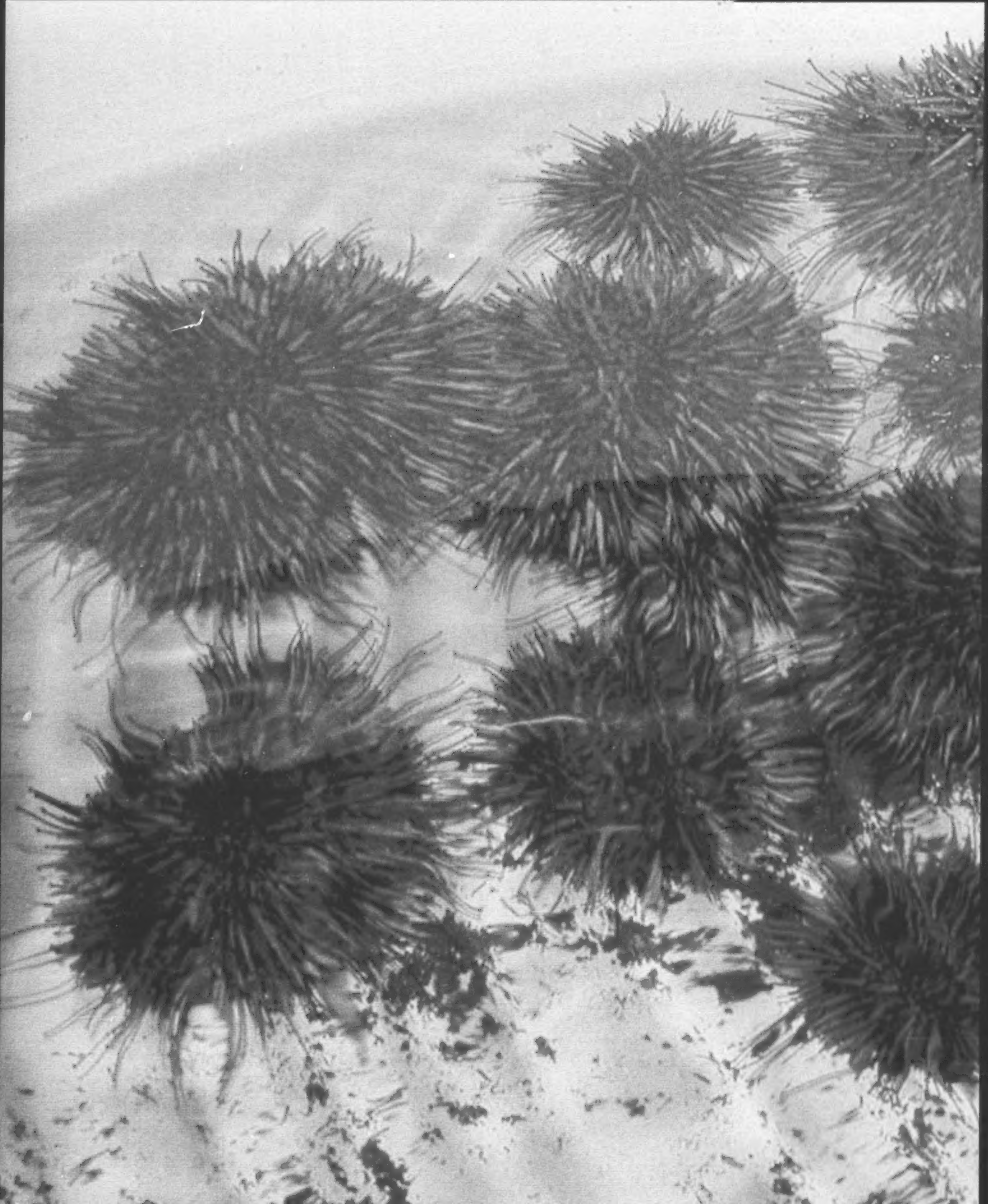
In addition, an independent peer review of the Forum's interim research findings from the two-year Broughton Research Program will be conducted.

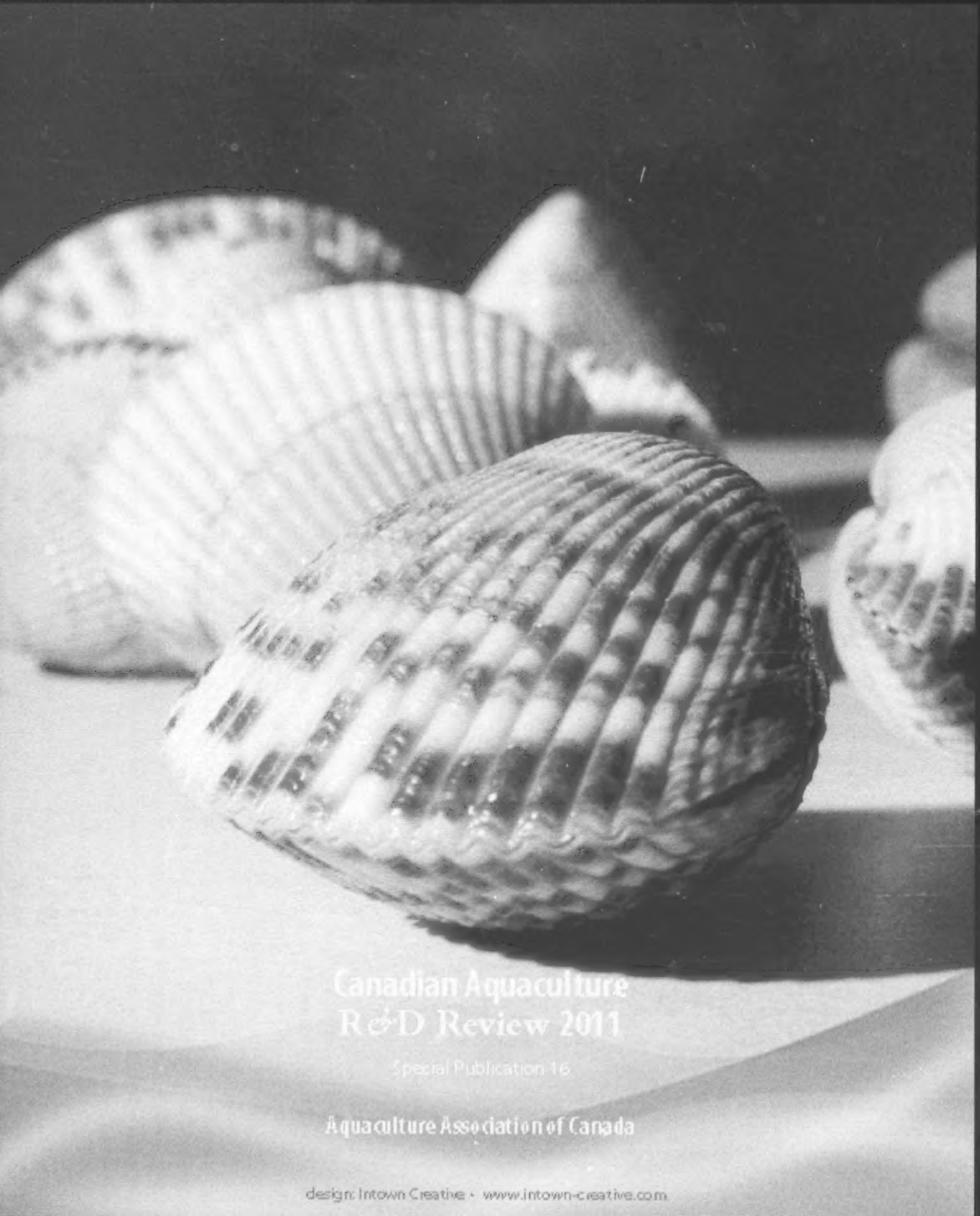
Forum members are also urging the Province to appoint an independent science secretariat to assume responsibility for future research to support an ecosystem-based management approach. This research is necessary to evaluate all development activities in BC watersheds and nearshore marine systems, improving public confidence that urban and industrial activity is being undertaken based on the best science available.

A copy of the Forum's Final Report and Recommendations along with research results and other contracted reports can be found at www.pacificsalmonforum.ca/research/index.php. This website will remain active for at least one year.

Glossary

AARS – Alma Aquaculture Research Station - University of Guelph
ACAIRDN – Atlantic Canada Aquaculture Research and Development Network
ACFFA – Atlantic Canada Fish Farmers Association
ACOA – Atlantic Canada Opportunity Agency
ACRDP – Aquaculture Collaborative Research and Development Program
AEG – Aquaculture Engineering Group Inc
AIF – Atlantic Innovation Fund
AIMAP – Aquaculture Innovation and Market Access Program
AVC – UPEI Atlantic Veterinary College
BC CAHS – British Columbia Centre for Aquatic Health Sciences
BCSGA – British Columbia Shellfish Grower's Association
BIO – Bedford Institute of Oceanography
CAISN – Canadian Aquatic Invasive Species Network
CAER – DFO Centre for Aquaculture and Environment Research
CAMP – Coordinated Area Management Production
CCFI – Canadian Centre for Fisheries Innovation
CeMIM–MAPAQ – Centre maricole des Îles-de-la-Madeleine
CEVAM – Centre d'Étude et de Valorisation des Algues Marines
CGP – Atlantic Cod Genomics and Broodstock Development Project
cGRASP – Consortium for Genomics Research on all Salmonids Project
CIDA – Canadian International Development Agency
CIMTAN – Canadian Integrated Multi Trophic Aquaculture Network
CLD – Centre local de développement des Îles-de-la-Madeleine
CSR–VIU – Centre for Shellfish Research, Vancouver Island University
CTPA – Centre technologique des produits aquatiques
CTSS – Centre de transfert et de sélection des salmonidés inc
CZRI – Coastal Zones Research Institute Inc (UMoncton Shippegan Campus)
DEPOMOD – a particle tracking computer model
DFA – Newfoundland and Labrador Department of Fisheries and Aquaculture
DFO – Fisheries and Oceans Canada
DFO–AIS – DFO Aquatic Invasive Species
EC – Environment Canada
EPAQ – École des pêches et de l'aquaculture du Québec
FCR – Feed conversion ratio
FQRNT – Fonds québécois de la recherche sur la nature et les technologies
FSCP – Fisheries Science Collaborative Program
GFC – Gulf Fisheries Centre
GRDI – DFO – Genomics Research and Development Initiative
HMSC – Huntsman Marine Science Centre
IFREMER – Institut français de recherche pour l'exploitation de la mer
IHNV – Infectious hematopoietic necrosis virus
IML – Institut Maurice-Lamontagne
IMR – Institute of Marine Research Bergen (Norway)
IMTA – Integrated Multi Trophic Aquaculture
INRS – Institut national de recherche scientifique
IOS – Institute of Ocean Sciences
IPSFAD – Interprovincial Partnership for Sustainable Freshwater Aquaculture Development Inc
IRAP – National Research Council Canada – Industrial Research Assistance Program
IRZC – Institut de recherche sur les zones côtières inc.
ISA – Infectious Salmon Anemia
ISMER – Institut des Sciences de la Mer
LARSA – Laboratoire régional des sciences aquatiques (U Laval)
MAMROT – Ministère des Affaires municipales, des Régions et de l'Occupation du territoire
MAPAQ – Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MDEIE – Développement économique, innovation et exportation
MHC – Marine Harvest Canada
MI – Memorial University of Newfoundland Marine Institute
MI —CASD – Memorial University of Newfoundland Marine Institute Centre Aquaculture and Seafood Development
MLI – Maurice Lamontagne Institute
MNRF – Ministère des Ressources naturelles et de la Faune
MUN – Memorial University of Newfoundland
MUNOSC – Memorial University of Newfoundland - Ocean Sciences Centre
NAIA – Newfoundland Aquaculture Industry Association
NBDAA – New Brunswick Department of Agriculture and Aquaculture
NBIF – New Brunswick Innovation Foundation
NL DFA – Newfoundland and Labrador Department of Fisheries and Aquaculture
NOCS – National Oceanographic Centre, Southampton, UK
NRC – National Research Council Canada
NRC–IMB – Institute of Marine Biosciences
NS DFA – Nova Scotia Department of Fisheries and Aquaculture
NSERC – Natural Sciences and Engineering Research Council of Canada
OSAP – Ontario Student Assistance Program
PARR – Program for Aquaculture Regulatory Research
PBS – Pacific Biological Station
PCBs – Polychlorinated Biphenyl Compounds
PCR – Polymerase Chain Reaction
PEIAA – PEI Aquaculture Alliance
PEI–DFARD – Prince Edward Island Department of Fisheries, Aquaculture and Rural Development
PIT – Passive Integrated Transponder
POP — Persistent Organic Pollutants
PSF – Pacific Salmon Forum
QTL – Quantitative Trait Loci
RAQ – Réseau Aquaculture Québec
RPC – Research and Productivity Council
RPPGR – Regroupement des pêcheurs professionnels de Grande-Rivière
RPPSG – Regroupement des Pêcheurs Professionnels du Sud de la Gaspésie
SABS – St. Andrews Biological Station
SFU – Simon Fraser University
SME – Small- and Medium-sized Enterprises
SODIM – Société de Développement de l'Industrie Maricole
SORDAC – Société de recherche et de développement en aquaculture continentale
SPI – Strategy for Partnerships and Innovation
SSHRC – Social Sciences and Humanities Research Council
STRADDAQ – Stratégie de développement durable de l'aquaculture en eau douce au Québec
SW - Seawater
T-PODs – fully automated, static, passive acoustic monitoring systems
UBC – University of British Columbia
UMCS – Université de Moncton campus de Shippagan
UNB – University of New Brunswick
UNBSJ – University of New Brunswick Saint John
UPEI – University of Prince Edward Island
UPEI–AVC – UPEI Atlantic Veterinary College
UQAR – Université du Québec à Rimouski
UQAR–ISMER – Université du Québec à Rimouski - Institut des Sciences de la Mer
USDA – United States Department of Agriculture
VHSV – Viral Hemorrhagic Septicaemia virus
VIU – Vancouver Island University





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